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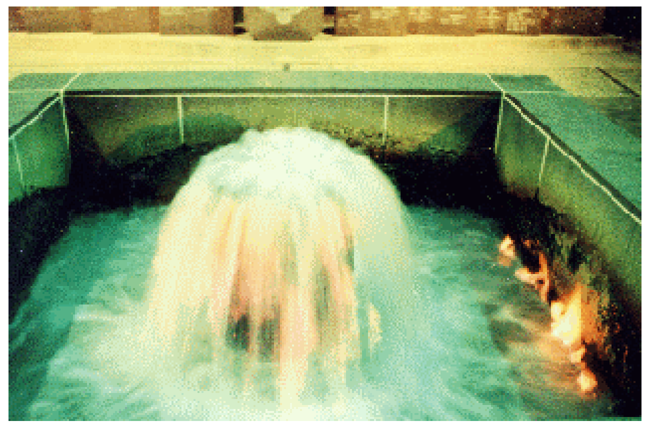
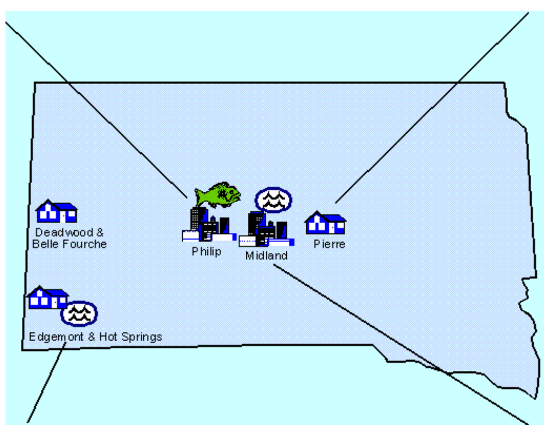
SOUTH DAKOTA GEOTHERMAL USES





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GEO-HEAT CENTER QUARTERLY BULLETIN

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS

Cover: Top left to bottom right – Philip, gas well in Pierre, Hot springs and Midland.

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SOUTH DAKOTA GEOTHERMAL RESOURCES

John W. Lund
Geo-Heat Center

South Dakota is normally not thought of as a geothermal state. However, geothermal direct use is probably one of the best kept secrets outside the state. At present there are two geothermal district heating systems in place and operating successfully, a resort community using the water in a large swimming pool, a hospital being supplied with part of its heat, numerous geothermal heat pumps, and many individual uses by ranchers, especially in the winter months for heating residences, barns and other out building, and for stock watering.

GEOLOGY AND RESOURCE BACKGROUND

The best known and most significant geothermal resource in the state is the Madison Limestone. It is well known as an aquifer and oil producing formation throughout the northern Great Plains and Rocky Mountains. The Madison (also known as the Pahasapa) contains about 179 miles^3 (746 km^3) of recoverable water with temperatures range from about 86^{o}F to 216^{o}F (30^{o}C to 102^{o}C) and a mean resource base is 2.78 x 10^{18} Btu (2,930 x 10^{18} J) (Gosnold, 1987 and revised in 1991). The Madison is one of the two geothermal aquifers that are presently used in direct-heat applications. The other is the Newcastle-Dakota Sandstone. Recent work, including eight potential geothermal aquifers, estimate the accessible geothermal resource base (about 0.001 times the resource base) of South Dakota as 12.52 Exajoules (10^{18}) or 11.88 quads as shown in Table 1 (Gosnold, 1991).

Table 1. Geothermal Accessible Resource Base for South Dakota

Formation	Resource Exajoules	Avg. Thick. m	Avg. Temp. ^{o}C	Max. Temp. ^{o}C
Dakota	0.42	36.5	18.5	73.4
Jurassic	1.22	81.9	42.5	71.5
Spearfish	0.66	43.8	57.7	82.3
Minnekahta	0.52	36.8	46.4	85.4
Minnelusa	2.02	134.1	47.3	86.5
Madison	2.93	153.7	51.0	90.3
Ord-Dev	2.90	140.2	53.7	97.2
Cambrian	1.85	110.0	56.1	104.8
Total	12.52			

* Temperatures are given for formation tops. Average thickness values are calculated from top to top. All of the formations named aquifers which may produce water. Higher temperatures are typical for the Williston Basin in northwestern South Dakota.

The Madison Limestone formation underlies at modest depths the western half of South Dakota. The recharge water is assumed to come from the Black Hills in South Dakota and the Big Horn Mountains and the Laramie Mountains in Wyoming (Applied Physics Laboratory, 1977). The Madison waters are considered potable in southwestern quarter of the state and are brackish in the northwestern quarter of the state.

The Mississippian age Madison Group is a sequence of carbonate rocks deposited over several western states including part of South Dakota, mainly west of the Missouri River (Figure 1). The sequence in South Dakota thickens from zero on the east edge to 1300 feet (400 m) in the northwest corner of the state (Figure 2) (Gries, 1977 and Martinez, 1981). After recession of the Mississippian seas, erosion and dissolution of the limestone created a karst topography. The Madison Group was then down warped into the Williston Basin to the north, and uplifted and eroded in the Black Hills to the west (Figure 3) (Schoon and McGregor, 1974). The depth to the top of the Madison varies from 1000 feet (300 m) in the east to over 7,000 feet (2,100 m) in the northwest (Figure 4) (Gries, 1977).

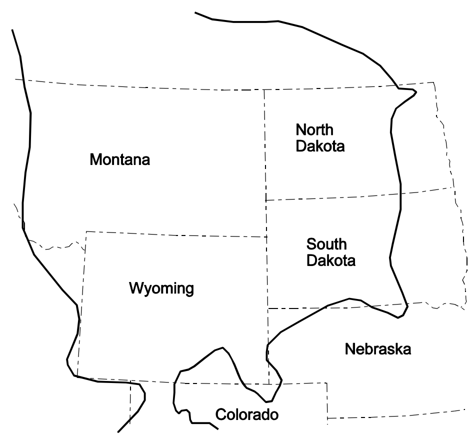

Figure 1. Extent of the Madison Group.

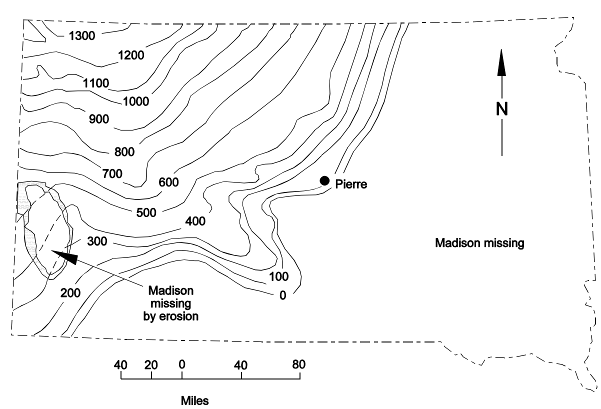

Figure 2. Thickness of the Madison Group.

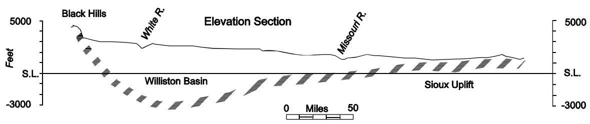

Figure 3. Profile of the state from Rapid City to Sioux Falls.

The average porosity of the Madison Group is 8% (Freeman and Meier, 1978) resulting from normal intergranular porosity, joint and fracture systems, and solution openings. Recharge occurs through infiltration of rain and snowmelt, and from water loss to sinkholes in limestone creekbeds in the Black Hills outcrop area. The average expected discharge for a properly constructed and developed well in the area is 500 gpm (32 L/s), with a range from 80 to 1000 gpm (5 to 63 L/s) (Gries, 1977).

Water temperature in wells in the Madison Groups is a function of depth to the resource - the typical gradient being near normal at 2°F/100 feet (37°C/km). Anomalous high gradients exist in the west central and southwest part of the state (exceeding 5.4°F/100 feet - 100°C/km) as shown in Figure 5 (Gosnold, 1991) and inferred from Figure 6 (Gries, 1977). Heat flow varies between 81 mW/m^2 and 112 mW/m^2 in the Madison (Gosnold, 1988).

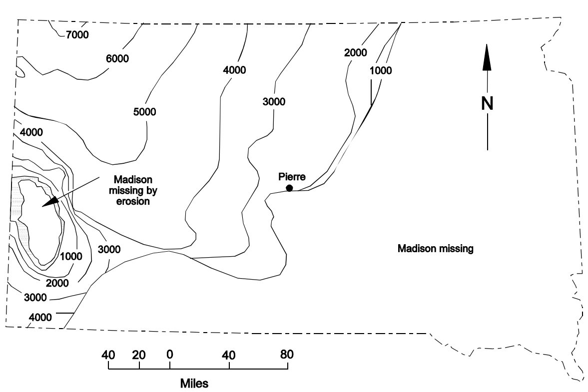

Figure 4. Depth to the top of the Madison Group.

Water quality varies widely, being best near the Black Hills and decreasing in quality radially outward. Disposal is not a major problem, however radium 226 has been detected in wells located in the west central portion of the state, and thus requires special treatment (see the article on Philip). Scaling of pipelines with calcium carbonate, calcium sulfate, silica or iron may occur if the water is allowed to cool and evaporate, but is normally not a problem. A bornite scaling (a black copper-iron-sulfate deposit) was observed by the author in a plate heat exchanger in the Midland School. Similar results were observed from testing using a corrosion test rack (Carda, 1978). Severe corrosion was experienced with "homemade" heat exchangers in the Philip Municipal Water Treatment Plant and in a commercial shell-and-tube heat exchanger in Midland. These has now been replace with plate heat exchangers, showing little corrosion problems.

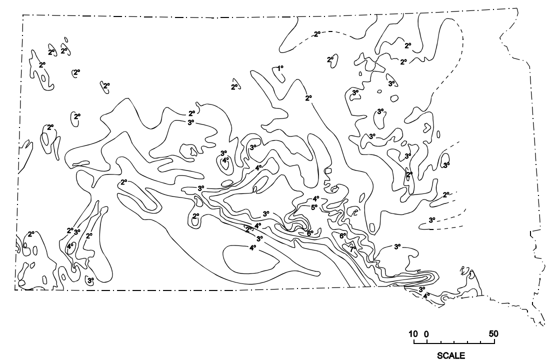

Figure 5. Geothermal gradient map modified from Schoon and McGregor (1974).

Examples of the Madison Group water quality is shown in Table 2 in ppm (mg/L) (Carda, 1978).

Table 2. Madison Group WaterQuality

Name	TDS	Temp	SO_4	Cl	Ca	Na
Edgemont	1140	130°F	280	257	130	180
Philip	1172	153°F	633	21	221	15
Midland	1462	160°F	736	28	272	18
EAFB*	1210	129°F	214	3	73	8

*Ellsworth Air Force Base near Rapid City

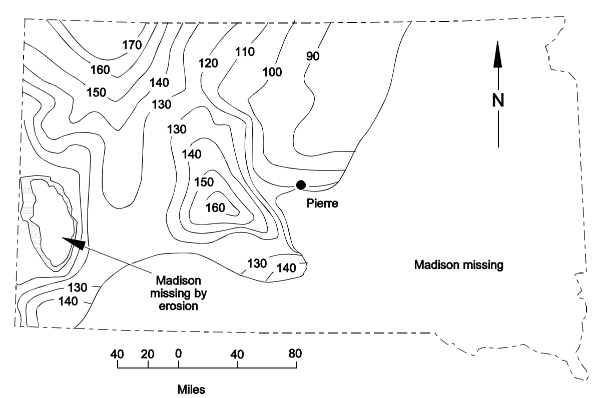

Figure 6. Isothermal map of the Madison Group.

EXAMPLES OF GEOTHERMAL DIRECT UTILIZATION

Early Uses

Warm artesian water from the Madison or Pahasapa Formation were observed as early as the 1880s in eastern South Dakota. The drilling of the first deep water well (2,983 ft) at Edgemont, Fall River County, 1910-13, demonstrated the potential of this formation. The flow of this well attracted attention because of its volume, 515 gallons per minute (32 L/s), its abnormally high temperature (130ºF [54ºC]) and its high shut-in pressure of 94 pounds per square inch (6.5 bar).

Subsequent drilling of a few municipal, military and industrial water wells, and a few hundred deep oil tests in western South Dakota, provided information on the quantity, quality, depth, temperature and pressure head on these artesian flows.

One of the earliest uses of geothermal water in the state was in Pierre, the state capital. A well was drilled on the capitol grounds in the winter of 1909-1910 to a depth of 1350 feet (411 m). This well produced 1,620 gpm (100 L/s) of 92ºF (33ºC) water. In addition, it produces 59 ft^3/min (28 L/s) methane gas. It was reported to have been used to heat the capitol building and provided gas for city street lights (according to the plaque at the well), however, it appears the gas was only used for lights in the capitol building. In the late 1950's the mains rusted out and the well was abandoned. However, the flow from the well stabilized and was run into a three-acre (1 ha) lake on the capitol grounds. In the mid 1960's the idea of a flaming fountain was conceived as a memorial for South Dakota's fallen military personnel. The flame was ignited in August of 1967 and has burned perpetually since that time (see cover photo).

Other early uses include bathing and spa therapy (balneology) in Edgemont, Midland and Hot Springs.

In Edgemont, near the southwest corner of the state, a small sanatorium and both house has been in operation for many years - the Pitman Bath House (Natural Resources Commission, undated) It featured hot sulfur baths from water that has total solids of 1097 ppm (mg/L) of which 317 ppm are sulphates, 250 ppm chlorides and 130 ppm calcium. It has a high concentration of hydrogen sulphide, which makes the water very corrosive. Two wells are used in the city, one drilled in 1910 and the other in 1935, at temperatures of 128ºF and 126ºF (53ºC and 52ºC) respectively. The city allowed the hot water to flow into an open reservoir for cooling before be used in the city system. The older well had its casing corroded sufficiently to allow leakage of the warm water from the Madison (Pahasapa) aquifer to mix with the sulphate water in the aquifer above (Leo sands of the Minnelusa formation) providing the hot sulfurous water used in the hot baths.

The Stroppel Hotel, located in Midland about 60 miles (100 km) west of Pierre uses warm water from a well drilled in 1939. The well, 1784 feet (544 m) deep, produced 33 gpm (2 L/s) of 116ºf (47ºC) water. Location of the well was based on known warm water wells in Capa and Nowlin on either side of Midland, but off the main highway. An addition was built onto the hotel to house three dressing rooms and three 8-ft by 8-ft (2.4-m x 2.4-m) separately enclosed bath tubs, each filled with four feet (1.2 m) of hot mineral water continually flowing through them. The hotel is also heated by the geothermal water (Figure 7). An analysis of the water gave a total dissolved solid content of 2686 ppm (mg/L), of which 1170 ppm is calcium carbonate and 850 ppm chloride (Natural Resources Commission, undated).

Figure 7. Stroppel Hotel in Midland. The baths are located under the sloping roof structure on the right.

Numerous warm springs have been used for swimming and balneology in the Hot Springs area that date back to before the turn of the century. These are discussed in a separate article in this Bulletin.

District Heating Applications

Two geothermal district heating projects have been developed in Philip and Midland.

The Philip district heating project was based on a Program Opportunity Notice (PON) solicitation and the resulting grant of cost shared funds to heat Haakon School and then cascade the geothermal water to heat downtown businesses. The project was completed in 1982 at a cost of $1.21 million. The well is 4,200 feet (1,280 m) deep, and produces 340 gpm (21 L/s) of 157º F (69º C) water. Eight buildings are heated in the downtown area before the water is disposed of in the Bad River. A special design was needed to remove Radium-226 from the spent fluid using barium chloride. A second geothermal well located about 2.5 miles (4 km) north on town, just west of Lake Waggoner supplies geothermal heat to the Haakon County highway equipment maintenance shop, the Water Treatment Plant and an aquaculture project. The details of these projects are discussed in another article is this Bulletin.

The Midland district heating project started in 1964 using a well on the hill behind town, however, today it uses a well drilled in 1969 that supplies 152ºF (67ºC) water. The high school and grade school were the original users of the heat, but over the years four buildings in the downtown area were hooked to the system, along with heating the concrete slab and wash water for a car wash. The water is finally piped uphill to a water treatment plant and then returned to the city as domestic tap water. Waste water is also used in a swimming pool and rancher in the winter will take of load of hot water to their ranch to thaw livestock watering troughs. The details of this system also appears to a separate article in this Bulletin.

St. Mary's Hospital

St. Mary's Hospital in Pierre was also the recipient of a PON grant to drill a geothermal well. The well, heat exchanger and connection to the heating system of the hospital was completed in 1980. The system uses 106ºF (41ºC) water from a 2,200-foot (670-m) artesian well drilled on the hospital property. The well originally produced 375 gpm (24 L/s), but now uses only 80 to 100 gpm (5 to 6 L/s) to heat about 35% of the building (60,000 ft^2 - 5,600 m^2). The savings amount to 25,000 to 30,000 gallons of fuel oil annually (95 to 113 tonnes). The project which cost $718,000, was 75% funded by the USDOE grant. This project is also discussed in more detail in this Bulletin.

Diamond Ring Ranch

This ranch is located about 40 miles (65 km) west of Pierre and had an existing well drilled into the Madison Formation at a depth of 4265 ft (1300 m) (Zeller et al., 1980). It supplied 152ºF (67ºC) domestic water, stock ponds and partial irrigation needs of the ranch for about 20 years. The well had a peak flow of 173 gpm (11 L/s) of highly corrosive water with high concentrations of SO_4 (>1000 ppm), Ca (>375 ppm), Cl (>175 ppm) and total dissolved solids of >2,000 ppm (mg/L). A space heating and grain drying project was proposed in 1980, and was funded by a USDOE PON grant of about $400,000. The space heating portion of the project involved retrofitting four residences, a shop, barn and garage (Figure 8). All were heated with forced air, except for the garage which used a floor slab heating system. The grain drier used a separate heat exchanger and was designed to replace the conventional propane grain drying system used for wheat, oats, barely and corn. Figure 9 is a schematic diagram of the geothermal system (Zeller et all., 1980). The geothermal water is disposed of into a stock pond. Conventional "off-the-shelf" items were used in the system, which included two stainless steel plate heat exchangers and PVC pipe reinforced with a fiberglass wrap. The capacity of the grain drier was 1.4 million Btu/hr (410 kW) and the space heating system 0.55 million Btu/hr (128 kW). Unfortunately, corrosion, fire in the residence and change of ownership, has caused the system to be abandoned.

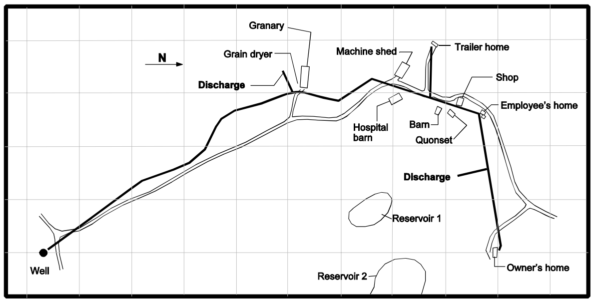

Figure 8. Layout of piping system for the Diamond Ring Ranch.

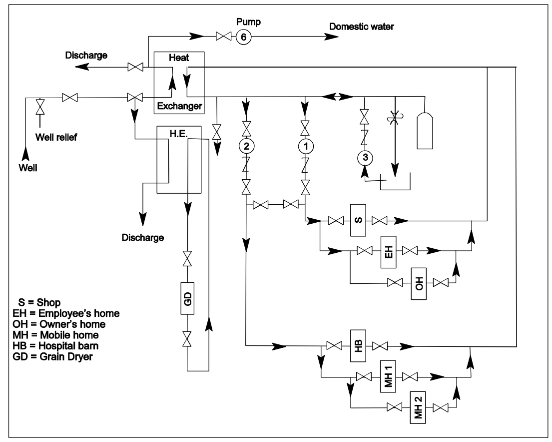

Figure 9. Schematic diagram of the geothermal heating system for the Diamond Ring Ranch.

Heat Pumps

Two major geothermal heat pumps systems have been installed in public buildings in Pierre for heating and cooling. A 45 ton (158 kW) unit has been installed in City Hall using 55ºF (13ºC) water at a maximum flow of 100 gpm (6.3 L/s) to heat 10,000 ft^2 (930 m^2) of floor space. The other system has been installed in the Discovery Center, a converted power station, used as a science museum for school children has a 125 ton unit (438 kW) for heating and cooling. It also uses 55ºF (13ºC) water.

Numerous cities throughout the state have installed heat pumps using the city water as the source for heating and cooling. These cities include Belle Fourche (127.5 tons - 446 kW - in the Community Center), Deadwood (in the City Hall - 60 tons - 210 kW, and the Visitors Information Center - 15 tons - 52.5 kW, Winter, and Hot Springs (described in the Hot Springs article in this Bulletin) (personal communication, Phil Nichols).

SUMMARY OF UTILIZATION

The following is an estimation of the installed capacity and geothermal energy utilization for South Dakota:

Table 3.

Source	Number	Installed Capacity MWt	Annual Energy Use 10^9Btu	Annual Energy Use GWh
Philip District Heating	1	1.59	11.5	3.37
Midland District Heating	1	0.10	0.8	0.24
Lake Waggoner	1	1.54	13.8	4.04
St. Mary's Hospital	1	1.28	4.1	1.20
Heat Pumps (Pierre)	2	0.45	3.4	0.98
Heat Pumps (cities)	5	1.32	9.8	2.89
Evan's Plunge	1	1.52	36.2	10.61
Swimming/Spa (others)	5	0.73	11.0	3.21
Ranch Heating	1000	10.55	78.8	23.10
TOTAL		19.08	169.4	49.64

This would amount to an annual savings of 30,000 barrels of oil equivalent.

ACKNOWLEDGEMENTS

I would like to thank Steve Wegman, utility analyist, South Dakota Utility Commission, Pierre; Phil Nichols, mechanical engineer, Rapid City; and William Gosnold, Jr., University of North Dakota, for their assistance in preparing the article.

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HOT SPRINGS, SOUTH DAKOTA

John W. Lund
Geo-Heat Center

Hot Springs, located in the southwest corner of South Dakota and on the southern edge of the Black Hills, is the only place where extensive development of curative waters (balneology) has been undertaken in the state. It is built along the banks of the Fall River, immediately below the junction of Hot Brook and Cold Brook (Figure 1 and 2). Hot Brook is so named because of the thermal springs originating along its banks and flowing into Fall River. It is entirely spring fed and thus is a dry channel above the Springer Ranch where the last springs flow into the channel. It is the water from these warm springs that are the basis for the hotel, baths and sanatoria that were once part of the city's industry (Natural Resources Commission, undated). The town should probably have been called Warm Springs, since the springs only range between 81º and 92ºF (27º and 33ºC). Except for Evan's Plunge, there is very little geothermal use in the town today. A combination in the lack of interest and belief in the therapeutic use of mineral waters, and corrosion and scaling of pipelines led to the demise of the industry in the 1950's.. There are over 80 capped wells and springs in town, however, there appears to be a slow revival of some of these past uses, especially the spa therapy (Beth Peters, personal communications).

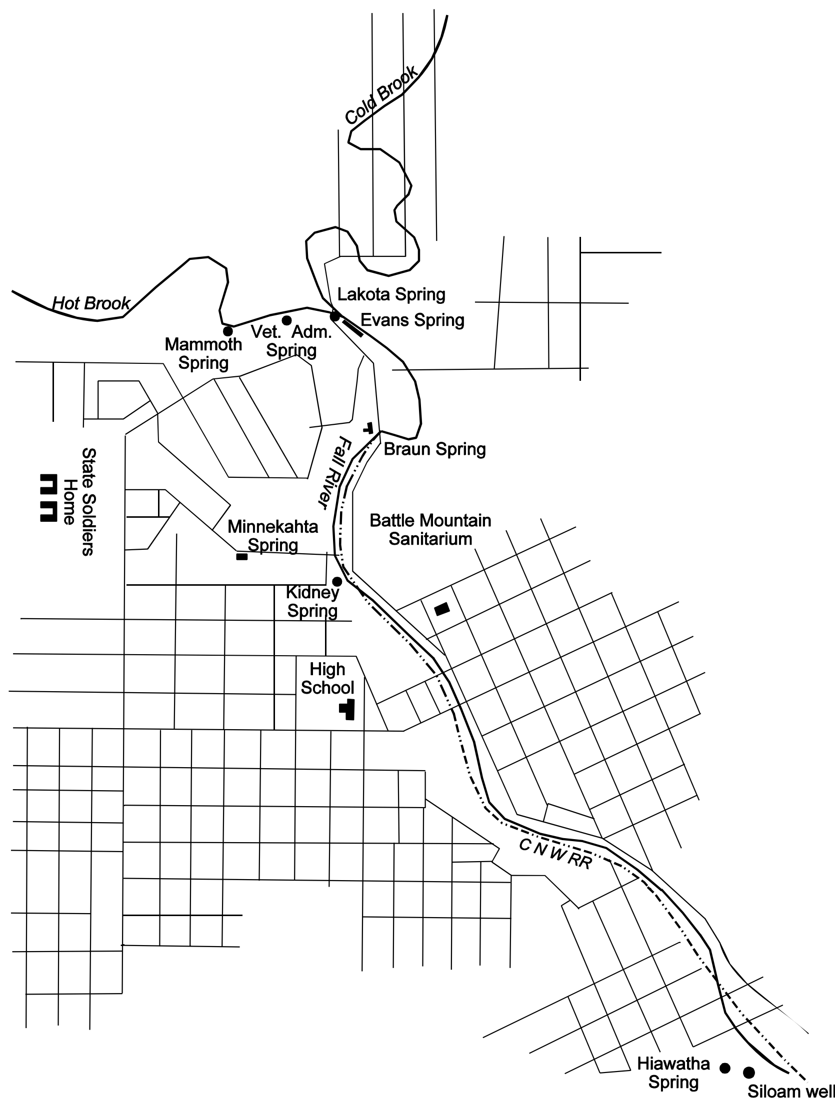

Figure 1. Map of Hot Springs showing the various hot springs.

Figure 2. Fall Creek looking downstream near Kidney Spring.

USE BY NATIVE AMERICANS

The Minnekahta Springs near the center of town was used by the Indians who had hollowed out a rock basin into which in the spring water flowed and was used as a bath tub. Most likely, the town received its name from this springs which means "Hot Water" in the Lakota Sioux language. In fact the city was first called Minnekahta and later changed to the English translation of the Indian word. A sign opposite Evan's Plunge states:

> "Long before the white man discovered the valley of healing waters, the Sioux and Cheyenne Indian tribes fought for possession of the natural warm water springs. Legend tells us that the battle ranged on the high peak above the springs and the Sioux emerged victorious."
>
> "The mammoth spring at the north end of the interior of the plunge is known as the "Old Original Indian Springs." Here the Indians drank and bathed in its warm healing water."

EARLY DEVELOPMENTS AND USES

In the springs of 1876, Colonel W. J. Thornby arrived at the present site of Hot Springs and "discovered" the source of the warm creek. Near the big spring where the Plunge was later built, he lopped off the top of a cedar sapling, blazed the trunk, and wrote with lead pencil: "This is my spring. W. J. Thornby" (Evan's Plunge brochure, undated).

In 1881 the spring was owned by Joe Brimdschmidt, who traded his rights to Joe Petty for a horse valued at thirty-five dollars. Petty in turn sold the spring to Dr. Stewart, who filed on the surrounding land. Finally, according to the sign opposite the Plunge (metric conversions inserted by the author):

> "The Evans Plunge was built in 1890 over numerous small sparkling springs and one mammoth spring of mineral water with a temperature of 87 degrees (31°C) and of medicinal qualities proclaimed on good authority, to be superior to that of the famous Warm Springs, Georgia."
>
> "From the inflow of 5,000 gallons of water per minute (315 L/s) from the springs arising out of the pebble bottom there is a complete change of water 16 times daily, thus insuring clean, fresh, living water at all times."
>
> "The pool 50 x 200 ft. (15 x 61 m), ranges in depth from 4 ft. to 6 ft. (1.2 to 1.8 m) with two shallow enclosures for children."
>
> "CHEMICAL ANALYSIS
> Prof. Charles B. Gibson
> of Chicago, Illinois
>
> Water temperature...............87 degrees
> Total residue........................87.9995
> Inorganic & non-volatile......4.9160
> Organic & volatile................8.050
> Sulphate of sodium...............8.824
> Sulphate of potassium..........3.331
> Sulphate of calcium.............16.290
> Nitrate of magnesium...........0.150
> Iron susqui-oxide.................0.260
> Alumina...............................0.021
> Silica...................................1.830"

The above numbers are probably in grains per gallon (x17.12 = ppm or mg/L), thus the total dissolved solids from the above would be: 87.9995 x 17.12 = 1506 ppm (mg/L).

Figures 3 and 4 are early photos showing the construction of Evan's Plunge and use in the 1890's (courtesy of Evan's Plunge).

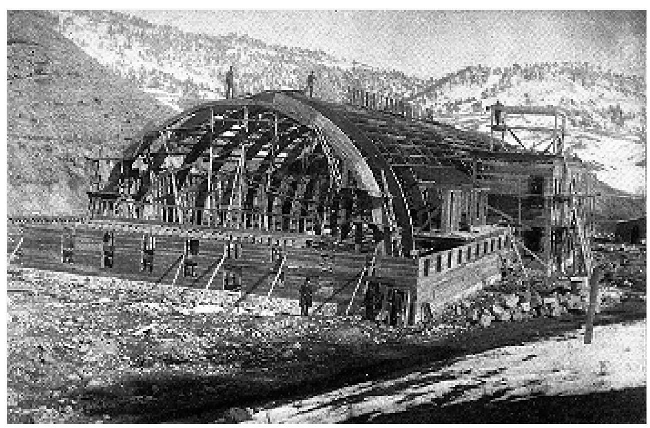

Figure 3. Construction of Evan's Plunge in 1890.

Originally, Evans Plunge and other mineral baths in Hot Springs were sought as a cure-all for a multitude of illnesses typical of other natural hot springs in the United States at the time. Dr. William E. Fitch (1927) stated: "They were (the springs) the resort of Indians long before the white man found his way into the jealously guarded realms of the Black Hills and were considered by the red man as a panacea for all ills. This water has been found useful in the treatment of chronic diseases of the gastrointestinal tract, diseases of the liver and biliary passages, and in rheumatism and arthritic joint disturbances, gout and others."

Figure 4. Users of Evan's Plunge in the 1890's.

DETAILS OF OTHER HOT SPRINGS

There are eight other large springs along Hot Brook and Fall River in addition to the springs used by Evan's Plunge. The total average discharge of all the springs, exclusive of Hot Brook is 22.92 cfs (649 L/s) and does not vary throughout the year. Hot Brook contributes an additional 1.98 cfs (56 L/s) (Rahn and Gries, 1973).

The upper springs on Hot Brook, Springer Ranch Springs, are the source of the city water supply. They produce over 1,000 gpm (63 L/s) of 81ºF (27ºC) water. The water in low in dissolved solids (398 ppm - mg/L) of which the majority is calcium carbonate (based on analysis by the State Chemical Laboratory in 1938), and thus was felt to have limited medicinal uses (Natural Resources Commission, undated).

Mammoth Springs is the first of the hot springs encountered in traveling down Hot Brook. It emerges from the base of a steeply dipping limestone cliff at 92ºF (33ºC), and has been used to supplement the flow from Evan's Springs to Evan's Plunge. An analysis by Charles B. Gibson and reported by the South Dakota Geological Survey in 1900 gave a total residue (dissolved solids) of 1420 ppm (mg/L) of which the major constituents were calcium sulfate at 618 ppm sodium sulfate at 398 ppm, potassium sulfate at 96 ppm, calcium chloride at 96 ppm, magnesium chloride at 70 ppm, and magnesium carbonate at 60 ppm.

A little further down Hot Brook is Veterans Administration Spring with temperature and chemical content similar to Mammoth Springs. The spring was developed by the Veteran's Administration for use in its local hospital. The spring was entirely enclosed in a concrete tank and thus the flow was concealed. The use of the water was stopped in the 1950's, with the speculation that the new medical staff did not believe in the benefits of mineral waters.

Lakota Springs located at the junction of Hot and Cold brooks has been used for drinking only. Its source appears to be the same as for Mammoth Springs. The name means "Indian" in the Sioux language, but was not the one used by the Indians for curative purposes.

Braun Springs was used by the Braun Hotel for baths and drinking water. Two springs were used by the hotel, both located on the west side of Fall River. Each springs was reported to discharge enough water to fill a two- or three-inch pipe (Natural Resources Commission, undated). The water temperature was 90ºF (32ºC) and had a total dissolved solids of 1496 ppm (mg/L) according to an analysis by Denton Dales (undated). The major constituents were calcium sulphate (428 ppm), calcium carbonate (351 ppm), sodium sulphate (296 ppm), sodium chloride (211 ppm) and magnesium sulphate (185 ppm) with a trace of silica, alumina and iron oxide. Since this water contained Epsom and Glauber salts and some common salt, they were useful for therapeutic purposes. Unfortunately, the springs are no longer used by the hotel, however the new owner is considering reopening the bath house in the basement.

The Minnekahta Springs, used by the Indians, was later used by the Hot Springs Hotel which operated a bath house and plunge (Figure 5). The source appears to be the same as

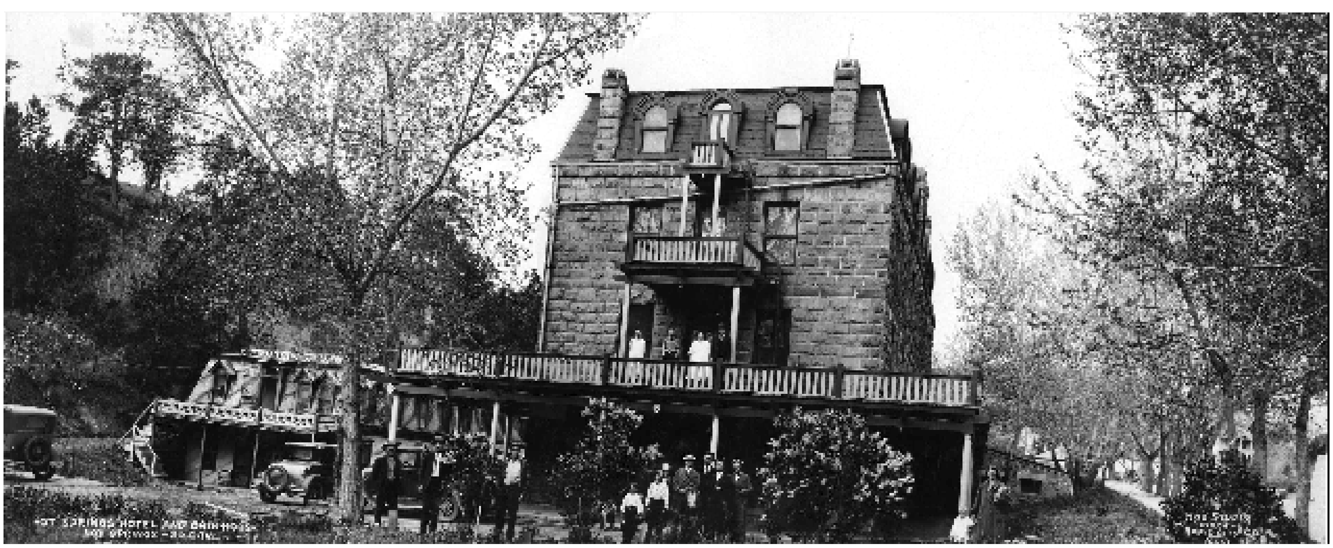

Figure 5. Hot Springs Hotel and Minnekahta Bathhouse probably taken in the late-1920's . Photo courtsey of Patty Hamm of Rapid City, whose grandmother, Anna May Carroll, is second from the right on the balcony.

Mammoth Spring with a temperature of 90ºF (32ºC) and a total dissolved solids of 1071 ppm (mg/L). These springs are again primarily sulphate and sodium chloride waters. The hotel was built in 1889 and the bathhouse was the first in Hot Springs. The complex was torn down in 1963-64 (source, Rapid City Journal, September 11, 1997).

Hygeia or Kidney Springs has a lovely gazebo, built in 1920, located next to it and is still a tourist attraction (Figure 6). In the past, the waters of this spring have been bottled and sold as an aid in the treatment of kidney diseases. A fountain located behind the gazebo is available to the public. A sign at the springs states:

> "Useful in the treatment of chronic diseases of the gastro-intestinal tract, diseases of the liver and biliary passages, disorders of the gento-urinary tract and in sluggish condition of the alimentary tract."

Figure 6. The gazebo at Kidney Spring with the drinking fountain on the right.

The springs, which issues from a conglomerate that caps the Pleistocene terrace of the valley opposite the Evans Hotel, is 83ºF (28ºC) has the following composition (as shown on a plaque at the gazebo):

sodium chloride	242.6 ppm
potassium chloride	68.4
magnesium chloride	118.0
lithium sulphate	15.2
calcium sulphate	704.0
calcium phosphate	2.76
silica	2.34

An analysis by Charles F. Metz made for the South Dakota State School of Mines (Natural Resources Commission, undated) gives a slightly different analysis. He reports a total solids content of 1789 ppm (mg/L) with a total sulphate content of 233 ppm and chlorides as 117 ppm.

Minnehaha or Catholican Springs and a well closed by, known as the Siloam Well, are now dry but once were the sites of resort hotels. They are the last springs in the Hot Springs district located about 1.5 miles (2.5 km) below Kidney Springs. At the time it was being used for a health resort, the first State Geologist, James Todd reported: "It comes from quite a different source from the others. Over it is erected a fine sanitarium capable of accommodating 100 guests. Temperature 82 degrees Fahrenheit. Siloam sanitarium close by is supplied from a well professing to have similar properties."

CASCADE SPRING

Cascade Springs, located about 8 miles (13 km) south of Hot Springs, is the largest single springs in the Black Hill of South Dakota (Rahn and Gries, 1973). It issues forth at the contact of the Minnekahta and Spearfish formations, and has a steady discharge of 67ºF (19ºC) and a total discharge of 22.5 cfs (637 L/s). Total dissolved solids are 2530 ppm (mg/L) with 1540 ppm sulfate, 568 ppm calcium, 235 ppm bicarbonate, 92 ppm magnesium, 62 ppm chloride, 60 ppm sodium, 22 ppm silica, 1 ppm fluoride, and <1 ppm iron. The pH is 7.0.

The Carlsbad Springs Company opened a 52 x 122 foot (16 x 37 m) cut-stone bath house and sanitarium in 1893. The interior was finished with highly polished marbles and hard wood, costly tiling, and French plate mirrors. The three-story 72-room hotel (96 x 87 feet - 29 x 26 m) contained 56 bath rooms, and hot and cooling rooms of marble (Carlsbad Spring Company prospectus, undated).

The original prospectus was issued for a capital stock of $600,000 divided into 12,000 shares. The company also proposed to develop 2500 lots. They state in the prospectus:

> "The springs (seven in number), whence the town derives its name, are located in a lovely valley. While all possess valuable medicinal properties, they differ greatly; the waters of one are identical with the famous Carlsbad Springs of Germany (now the Czech Republic); another's are strongly impregnated with iron; a third with magnesia; a fourth with sulphur; while still another's are largely composed of phosphates."
>
> "These wonderful waters relieve and cure rheumatism, gout, stiff joints, contractions of muscles and skin, old wounds, skin diseases, scrofula, scrofulous ulcerations and enlargement of glands, prostrations from long standing sickness or from debility following the use of powerful medicines, spinal diseases, sciatica, lumbago, neuralgia, nervous affections, partial, progressive, lead and writer's paralysis, St. Vitus dance, muscular and general debility, catarrhs of all kinds, dyspepsia, Bright's disease, diabetes, goitre locomotor, ataxia, blood poisons, anaemia, spanormia, hemorrhoids, piles, uterine diseases, change of life, sterility, mercurial disease and mercuria, and on spholetic lesions these waters have a marvelous effect on these loathsome and obstinate affections."
>
> "The chemical analysis of these waters show them superior as a remedial agent to any others heretofore in use. Rheumatism, a disease primarily of the kidneys, but affecting the muscles and joints

from uric acid, is invariably cured by these waters. No failure of a case need be recorded if the patient will use a proper course of treatment at Cascade Springs."

Several stone buildings and a group of dwelling houses were erected in this proposed resort city. The railroad failed to come through, however, and the town was abandoned. The only building left at the site is an old bank building uses as a private residence. The bath house and sanitarium foundation was recently excavated and indicates the massive size of the stone block (Figure 7 and 8).

Figure 7. Excavated foundation for the Carlsbad Spring Company bathhouse and sanitarium at Cascade.

Figure 8. Detail of the excavation. Note the individual bathroom to the left of the people and the old bank building in the background.

CURRENT GEOTHERMAL DEVELOPMENTS

Only two major uses of the geothermal waters are made in Hot Springs today: at Evan's Plunge and a heat pump installation at the Mueller Civic Center and Chamber of Commerce building. There are also several homes that use the geothermal water for heating (Beth Peters, personal communication).

Evan's Plunge uses the geothermal springs in the bottom of the pool to supply the 86°F (30°C) water at about 5,000 gpm (315 L/s) (Figure 9). In addition, a 10-ton (35 kW) heat pump is used for space heating and cooling of the weight lifting/exercise room. The spring water is passed through an Alfa-Laval plate heat exchanger (Figure 10), and the secondary water supplied to the heat pump and also directly to an air handling unit to help control the humidity in the building. The waste water from the heat exchanger is then run to an outside water slide and pool, and then finally dumped in the river. The water could not be used directly in the heat pump and air handling unit due to CO_2 gas that caused corrosion in copper pipes. This gas was not detected or reported in the original analyses cited above.

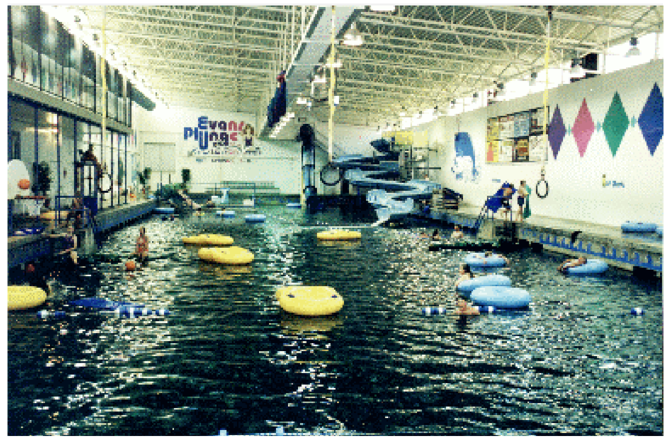

Figure 9. Inside Evan's Plunge

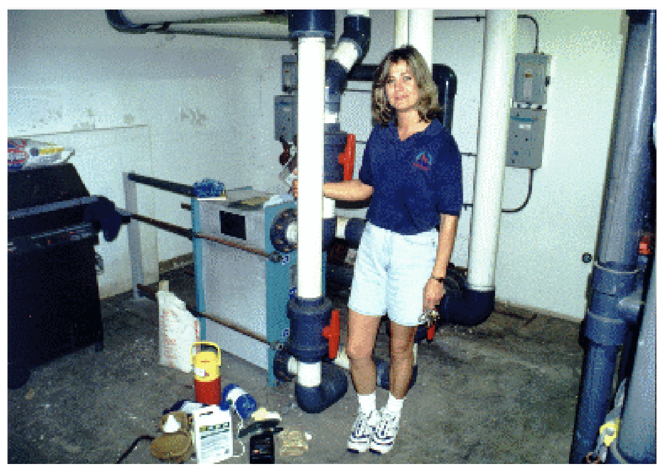

Figure 10. The plate heat exchanger used with the heat pump system.

The Mueller Civic Center also uses a heat pump for heating and cooling. The source is the Fall River, where initially the river water was used directly in the heat pump. However, fine grained material in the river water fouled the compressors, which eventually had to be replaced. Finally, a mat of pipes were a placed in the bottom of the river to form a closed loop system. Six units are now in operation for a total of 77.5 tons (271 kW).

CONCLUSIONS

Hot Springs has had an important geothermal past, when baths and balneology were popular. Unfortunately, due to lack of interest and support by users and the medical profession, interest in development and use declined. The good news is that there is a small group of people in the community, led by Beth Peters, who are attempting to resurrect the use and therapy of hot mineral baths (Figure 11). New construction is being proposed, including the reuse of the springs at the Braun Hotel. As stated in the conclusions of the Natural Resources Commission study:

> "Waters from small springs can, in some instances, be developed into watering places and health resorts with either high temperature or dissolved salts as added inducements."
>
> "It is hoped, however, that what has been given here (in the report) will be used in pointing out that South Dakota should not be overlooked as a place suitable for health resorts not only for the use of its own citizens but for the benefit of outsiders who come to the State to enjoy its recreational facilities and engage in business."

Figure 11. Sign over the Springs Bath House.

ACKNOWLEDGMENTS

I would like to thanks Beth Peters owner of the Springs Bath House, and Don and Robin of Evan's Plunge for their assistance during my visit.

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DESCRIPTION AND OPERATION OF HAAKON SCHOOL GEOTHERMAL HEATING SYSTEM

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INTRODUCTION

Haakon School is located in the city of Philip, near the Badlands National Park in the southwest quadrant of South Dakota. The town overlies the Madison Formation which is a large-area aquifer. The aquifer has a demonstrated capability to produce geothermal water. A system to tap this potential and heat the Haakon School District buildings in Philip has been in operation since November 1980. Five school buildings having a total area of 44,000 ft^2 (4088 m^2) are heated with 157^{o}F (69^{o}C) water. A single well provides water at a maximum artesian flow of 340 gpm (21.5 L/s, which more than meets the heat demand of the school buildings. Eight buildings in the Philip business district utilize geothermal fluid discharged from the school for space heating. During the 1980-81 heating season, these buildings obtained 75% to 90% of their heat from geothermal fluid. Peak heat delivery of the system is 5.5 million Btu/h (1.61. MJ/s), with an annual energy delivery of 9.5 billion Btu (10 TJ).

The geothermal system has operated nearly problem free with the exception of the equipment to remove Radium-226 from the spent fluid. Barium chloride is added to the water to precipitate sulfates containing the radium. Accumulation of precipitates in piping has caused some operational problems.

SYSTEM DESCRIPTION

Geothermal water flows from the well at 157^{o}F (69^{o}C) and is first used to heat the armory/high school building and elementary school buildings. Fluid discharged from the schools and armory is then used for space heating of buildings in the Philip business district. Eight buildings are currently connected to this system. Spent geothermal fluid is treated for Radium-226 removal prior to disposal in the Bad River. A flow diagram for the system is shown in Figure 1.

The artesian well is located about 170 ft (52 m) northwest of the armory/high school building. Total depth of the well is 4,266 ft (1,300 m), and maximum flow is 340 gpm

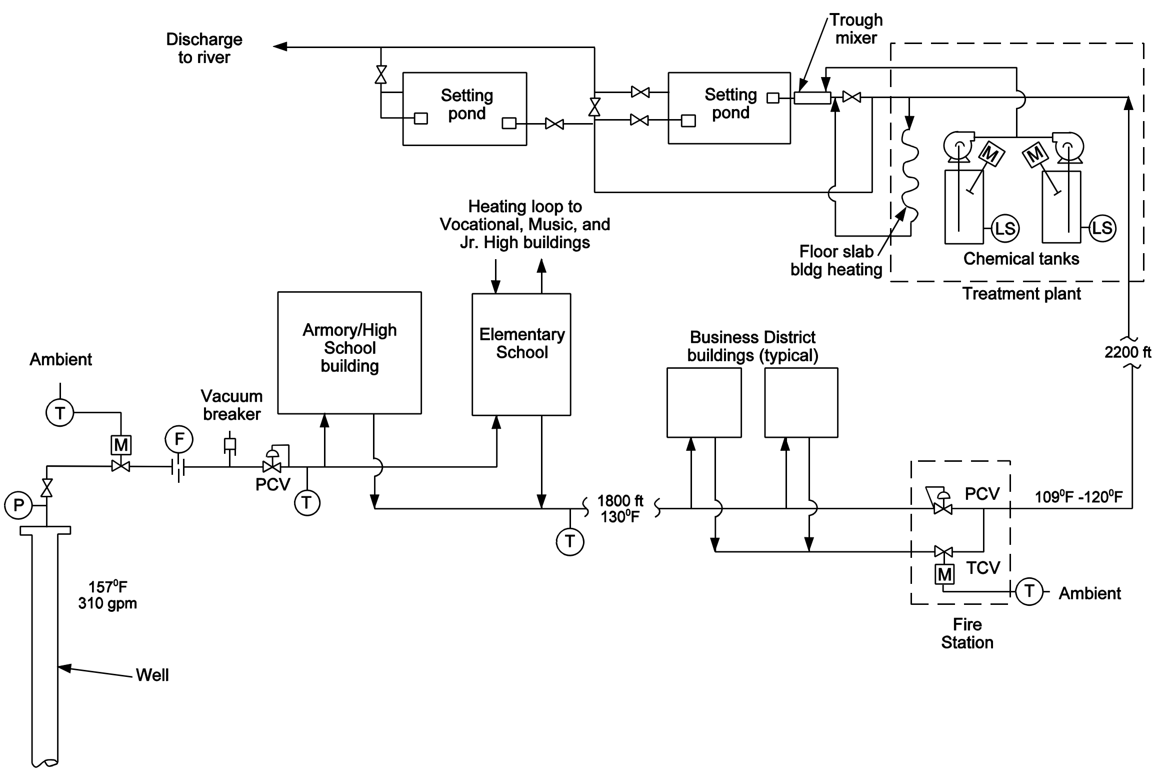

Figure 1. Haakon School geothermal system schematic.

(21.5 L/s). The water has a total dissolved solids content of 1,112 ppm and a pH of 7.4.

Buildings heated by the geothermal fluid include the high school building (also heating the National Guard Armory), the elementary school building, a vocational-agricultural education building, and two music buildings. The floor area of the high school building is 20,088 ft^2 (1,866 m^2), and the elementary school building is 15,356 ft^2 (1,427 m^2). Both buildings were previously heated with oil-fired steam boilers. The 6,252 ft^2 (581 m^2) vocational building previously had electrical resistance heating. Propane space heaters were used in the 1,550 ft^2 (144 m^2) instrumental band and 792 ft^2 (74 m^2) vocal music buildings.

Water and space heating equipment in the elementary school boiler room is shown schematically in Figure 2. The armory boiler room is very similar. Buried, fiber reinforced plastic pipe transports the geothermal fluid to the two boiler rooms. There it passes through two plate-type heat exchangers.

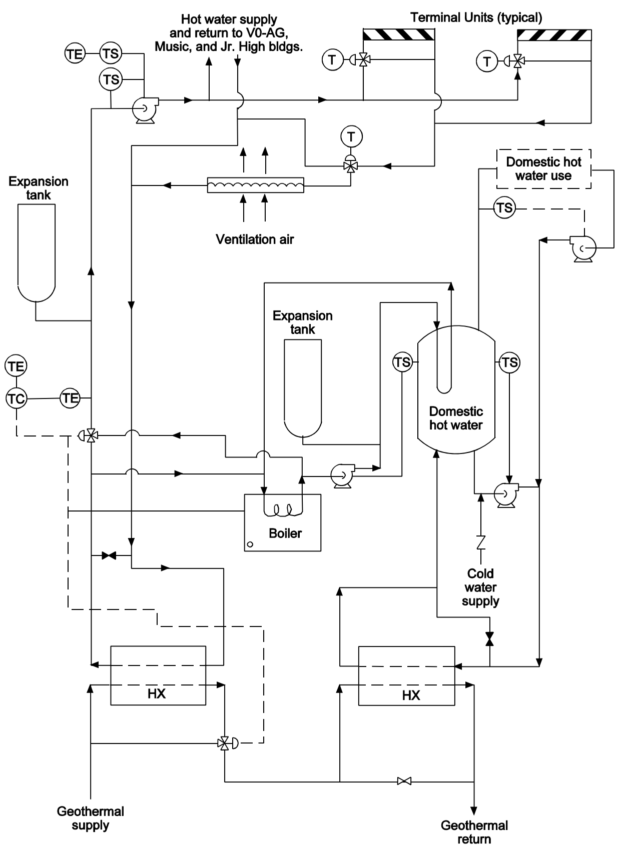

Figure 2. Haakon Elementary School geothermal heating schematic.

The exchangers are off-the-shelf- items. Each unit uses 316 stainless steel plates and nitrile gaskets. One unit heats water in a closed heating loop and the second heats domestic hot water. The elementary school boiler was modified to convert it from steam to hot water production. The armory boiler was in poor condition and was replaced with several, small new hot-water units. Both boiler systems are in series with the geothermally-heated hydronic systems to provide backup and peaking. Backup domestic water heating is provided by the boilers via a heat exchanger in the domestic hot water storage tank. Since the initial startup, the boilers have only been needed once. That was during a 2-hr period when the wind chill was -55ºF (-48ºC). In addition to heating the elementary school, the hydronic system also supplies the vocational-agriculture and music buildings. The junior high school is in the process of being added to the system.

Terminal units included modified and new equipment. Ventilators, fan coils, and unit heaters were modified to accept water coils in place of steam coils. Baseboard radiation units are used, as is; but, additional units were added to maintain heat capacity with 145ºF (63 ºC) water instead of 225 ºF (107ºC) steam.

The geothermal discharge from the school is transported in a single pipe which becomes the supply line through the downtown area. A disposal line begins at the upstream end of the business district and parallels the supply line from the school to the last user on the system, the fire station. From there, a single line continues to the radium removal plant and disposal in the Bad River.

Eight buildings in the business district are presently connected to the system. Application methods vary, although all use fan coils of some sort. Some use the geothermal water directly in existing coils, some in new copper coil unit heaters or coils placed in existing duct work. One uses new stainless steel coils in existing duct work, and one uses a shell-and-tube heat exchanger to heat a hydronic loop.

Water leaving the business district flows to the water treatment plant where Radium-226 is removed. The water is then discharged to the Bad River. The geothermal fluid naturally contains about 100 pCi/L (pico Curies/liter) of Radium-226 as radium sulfate. The allowable EPA limit for drinking water is 10 pCi/L (5 pCi/L background plus 5 pCi/L in the fluid).

Barium chloride (as 10% aqueous solution) is added to the water to cause formation of barium sulfate from sulfates already present. Barium sulfate and radium sulfate then co-precipitate. Precipitates are allowed to settle in the pond (3-day retention time) before water is discharged to the Bad River.

The barium chloride addition rate is fixed to give 2.6 ppm $BaCl_2$ at maximum geothermal flow. Automatic adjustment to maintain this concentration at lower flow is not provided. Barium chloride mix tanks and pumps are housed in the water treatment building. The solution is added at a baffled trough which empties into the pond. Only one pond is in use.

Sludge collects on the pond bottom at a rate of about 85 ft^3 (2.3 m^3) per year. Sufficient liquid volume will be maintained throughout the pond's 30-year life. Radioactivity accumulates at 0.06 curies/year. At the end of pond life, the sludge can be removed to a disposal site or mixed with cement to form the bottom for a new pond build directly over the old one.

Control points for the system are shown schematically in Figures 1 and 2. Flow of geothermal fluid from the well is regulated by a valve and controller responding to ambient temperature. Full flow is achieved at, and below, 30ºF (-1ºC) and minimum flow (about one third open) occurs between 60 and 65ºF (16 and 18 ºC). Minimum flow is maintained at higher temperatures to provide energy for domestic hot water heating. A pressure reducing valve located just downstream of the flow control valve maintains approximately 20 psig (138 kPa) in the system leaving the well house.

Equipment in the fire station (downstream of the business district distribution system) controls system pressure and regulates flow through the business district loop. A motor operated flow control valve on the return line is set to be full open at 20ºF (-7ºC) and full closed at 65ºF (18ºC). A second valve maintains back pressure in the distribution piping to minimize calcite precipitation.

The temperature of the hydronic fluid leaving the geothermal heat exchangers and ambient temperature determine geothermal flow rate to the heat exchangers. The temperature of the hydronic fluid is maintained between 90 and 140ºF (32 and 60ºC). Circulation in the heating loop is controlled by ambient and fluid temperatures. Pumps are activated at outside temperatures below 64ºF (18ºC) and are shut off when temperature exceeds 66ºF (19ºC) and no heat is needed. The pumps are also deactivated when hydronic fluid temperature is below 65ºF (18ºC). This avoids wasting pumping energy. Room thermostats control flow through terminal units.

When outside temperature is below -10ºF (-23ºC) and hydronic fluid temperature is below 90ºF (32ºC), the backup boiler is turned on and automatically valved into the system. During boiler operation, hydronic fluid flows first through the geothermal heat exchanger, and then through the boiler.

The geothermal fluid flows continuously through the domestic water heat exchanger. Flow of portable water through the heat exchanger occurs during make up due to water consumption and when the recirculating pumps are running. One pump operates as needed to circulate a small flow through the building supply loop to maintain a ready supply of hot water at the taps. The second pump starts automatically when storage tank temperatures falls below 115ºF (46ºC) and circulates water from the tank through the heat exchanger. Further drop in domestic hot water temperature below 105ºF (41ºC) will activate the boiler.

OPERATING EXPERIENCE

The completed system began operation in November 1980. During the remainder of the 80-81 heating season, the schools obtained all of their heat from the geothermal fluid. Only one business obtained geothermal heat during the first season. The following winter, the schools were heated entirely with geothermal energy except for a 2-hr period when supplemental heat was provided by the boiler. This occurred because the wind chill factor was -55ºF (-48ºC). Geothermal energy delivered to the school buildings during that heating season was 8.11 billion Btu (8.55 TJ). This displaced 10.5 billion Btu (11.1 TJ) of electricity, fuel oil and propane.

Eight more businesses were connected to the system for the 81-82 heating season and geothermal supplied 75 to 90% of their heating energy requirements.

Plugging of pipes at the water treatment plant has been a significant operating problem. Barium chloride was added to the water at a static mixer in the treatment building. Sulfate deposits partially plugged the mixer and pipe downstream of the mixer, and frequent cleaning was required. Installation of the current trough system for $BaCl_2$ addition and mixing has solved these problems.

Performance of the control system has been very satisfactory as far as the users are concerned. They have had reliable, economical heating. The operation has been unsatisfactory in terms of utilizing the resource efficiently. As operated, the school system extracts between 8 and 16ºF (4 and 9ºC) from the geothermal fluid, depending on load. This has been adequate to meet the schools needs; but, the flow rate is usually much higher than needed. In addition to inefficient use of the resource, barium chloride is wasted by treating the excess water. During a prolonged period of -35ºF (-37ºC) weather, the lowest temperature of the water reaching the disposal point was 128ºF (53ºC). It appears that the business district users are also somewhat inefficient in their use of the resource.

The remainder of the system has performed well. There have been no scaling or corrosion problems. This is attributed to the material selection being based on corrosion coupon tests with the actual geothermal fluid. The heat exchangers were opened and cleaned in May 1982. No evidence of corrosion or deposits were found on the geothermal side. Minor iron oxides deposits found on the domestic hot water side were believed to have been from the hot water storage tank. Annual inspection and cleaning should be more than adequate.

ECONOMIC EVALUATION

Total capital costs for the Haakon geothermal system are estimated to be $1,218,884. Expenditures through September 1983 were $1,209,185. Future spending will cover system monitoring and a final report.

$934,326 or 77% has been DOE money. Remaining funds were provided by the Haakon School District ($213,669), businesses connected to the district heating system ($52,110), and Brookhaven National Laboratory for a test of polymer concrete pipe in the system ($9,080).

Total costs for the complete geothermal system were originally estimated to be $438,763. Costs for the well, distribution system, and building conversion all exceeded estimates. Construction of a water treatment plant and district heating system added expenses that were not included in the original estimate.

Annual operating and maintenance costs for the entire system total nearly $4,000. Annual energy displaced is about 123,000 kWh electricity, 55,000 gallons (208 m^3) of fuel oil, and 24,000 gallons (91 m^3) of propane.

Three factors had a significant impact on the cost of the project. The building retrofit costs were significant. Every room in each building had to be converted from steam heating, electrical resistance heating or propane to hot water heating.

The armory/high school boiler was obsolete and was replaced with new modular units. The boiler in the elementary school was modified to convert it from steam to hot water production.

The agreement between the school district and the business district is the second significant factor. The business district currently saves an estimated $47,500 each year, but only pays $2,500 to the school district.

Finally, the geothermal system could greatly increase its profitability by changing its operating philosophy. The school boilers could be used for peak heating during the severest weather. This would allow the school district to sell considerably more heat to the business district at very little additional cost to the school district.

It was observed that the school removes about 16ºF (8.9ºC) an the business district removes about 11ºF (6.1 ºC) from the peak flow rate of 340 gpm (21.5 L/s). This was under the extremely cold conditions -35ºF (-37 ºC) which occurred once in the last three years. The system was designed for a usable temperature drop of 32.35ºF (17.97ºC). Even at this extreme condition, only 83% of its design capacity was used.

CONCLUSIONS

Equipment is readily available which will give reliable service in a geothermal environment. However, it should be carefully selected based on adequate corrosion testing.

The economics of the project would be much improved if: there had been no radium removal plant required, the retrofit would have been less expensive, the business district users had paid a larger percentage of their energy savings to the school district, and the school boilers were used for peaking to generate more revenue.

The control system should be adjusted to more fully utilize the resource particularly under partial load conditions. This may be difficult due to the redundancy and complexity of the present system. If necessary, the control system should be modified to make it more responsive to the varying heat demand. Conserving the resource should be a basic objective to assure its availability to a maximum number of future users. In addition, using the geothermal water more efficiently would reduce operating costs by using less barium chloride.

ACKNOWLEDGMENTS

The authors would like to acknowledge the cooperation of Roland Smit and Reed Drury of Haakon School District No. 27-1, and Ray Hengel of Hengel, Lattimer & Associates in the preparation of this paper. The project was performed by the Haakon School District under DOE Cooperative Agreement No. DE-FC07-78ET27080, which was administered by the Department of Energy, Idaho Operations Office. Technical assistance was provided to the project by EG&G Idaho under DOE Contract No. DE-AC07-761001570.

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EDITOR'S NOTE

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The original article reported nine buildings on-line in the downtown area; but, only eight are known today.

PHILIP, SOUTH DAKOTA GEOTHERMAL DISTRICT HEATING SYSTEMS

John W. Lund
Geo-Heat Center

The Philip geothermal district heating project, which uses the waste water from the Haakon School, has now been in operation for 15 years. The origins of this project is discussed in the article by Childs, et al., (1983), presented in an abbreviated form in this issue of the Bulletin. This project was one of the 23 cost shared by USDOE starting in 1978, of which 15 became operational. The city district heating system was added on to the original USDOE cost shared project for the Haakon School (named after King Haakon V of Norway). The 4266-ft. (1,300-m) deep artesian well can provide up to 300 gpm (19 L/s). It has a shut-in pressure of 52 psi (3.6 bars) and will flow naturally at 15 gpm (0.9 L/s) (Fig 1).

Today, there are eight buildings in downtown Philip using the geothermal heat as shown in Figure 2. The waste water from Haakon School is delivered downhill in a single six-inch (15-cm) preinsulated FRP pipeline to town at 120 to 145°F (49 to 63° C), depending upon the outside temperature and the amount of heat extracted at the school. The pipeline

Figure 1. Haakon School well with maintenance person William DeLayne.

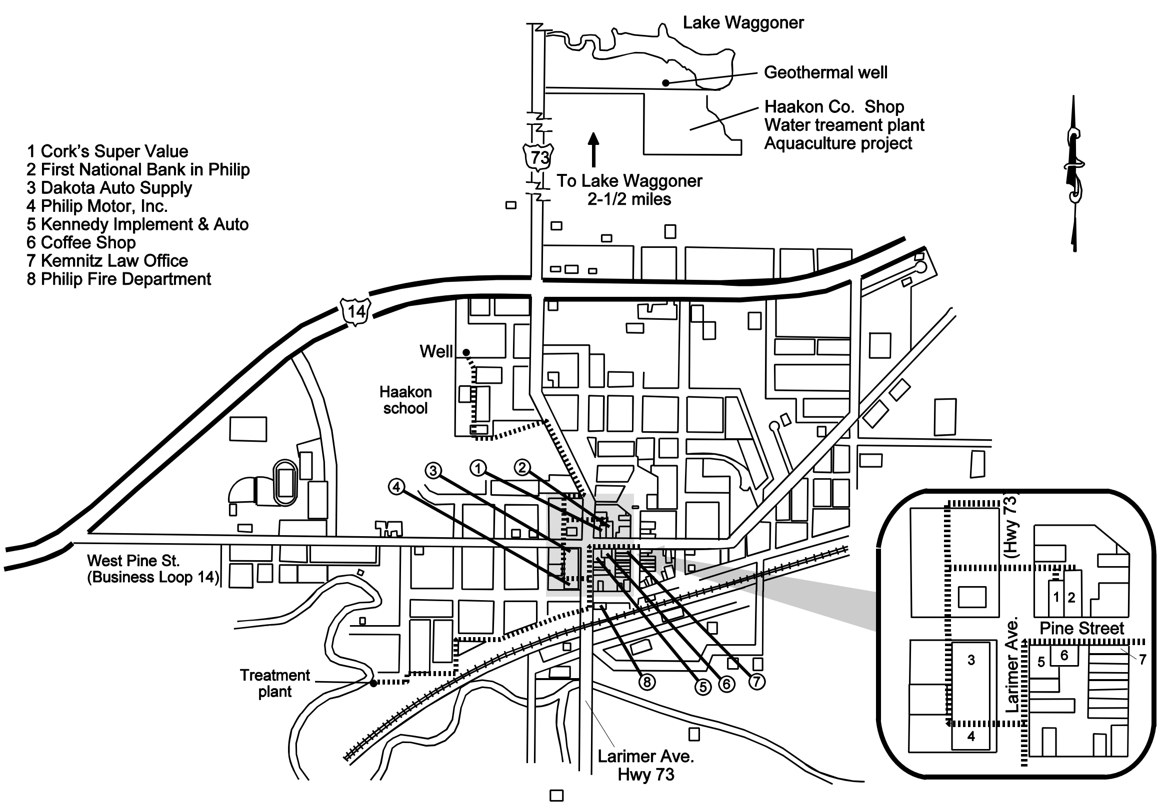

Figure 2. Philip district heat system schematic.

is buried at a depth of eight feet (2.4 m) to be below the five to six feet (1.5 to 1.8 m) of frost penetration in the winter. A 10 to 15ºF (6 to 8ºC) ΔT is removed from the water in two separate distribution loops. When the outside temperature reaches -20ºF (-29ºC), propane backup heating is used. The pressure is balanced at the fire station, the last building on the system before the water reaches the barium chloride treatment plant. Due to the radium 22, barium chloride is used to treat the water before being wasted to the Mad River. The treatment plant has two 90 ft x 158 ft by 10 ft deep (27 m x 48 m x 3m) storage ponds that will each hold 374,000 gallons (1,416 m^3).

Initially, the city businesses were retrofitted with cast iron heat exchangers at a cost of $30,000, however, due to corrosion, these were replaced with stainless plate heat exchangers (Fig. 3). Treated water is then used in a closed loop in each building. Heat in the various building is supplied either through Modine heaters, unit heaters, or by piping in the floor (Fig. 4 and 5). The Philip Geothermal Corporation (for profit) now pays the school district $5,000, carries a $1,000 liability policy, pays taxes, and spends about $500 for repair, for a total annual cost of about $6,500. Each user pays a share of the cost based on the percentage of the water used. For example, the bank pays 17% of the annual cost and saves $7,000 to $9,000 per year in heating costs (Fig. 6). The total savings for all eight buildings is over $100,000 annually, whereas the school district saves $175,000. Thus, the consumer pays about 20% of the corresponding cost of propane or fuel oil, the alternate fuel in the area.

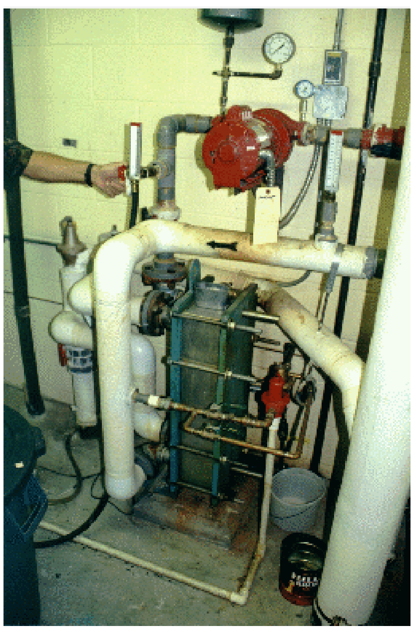

Figure 3. Plate heat exchanger in First National Bank building

Figure 4. Modine ceiling heater in Philip Motor, Inc.

Figure 5. Floor heating loops in the Philip Fire Department.

Figure 6. Corky's Super Value and First National Bank buildings.

LAKE WAGGONER

A second well, drilled by the city to a depth of 5280 feet (1,600 m) (Fig. 7), and is located near Lake Waggoner, about 2.5 miles (4 km) north of town, can produce 700 gpm (44 L/s) at 157ºF (69ºC) with a shut in pressure of about 80 psi (5.5 bars). The water from the well is used to heat the Haakon County water treatment plant and highway maintenance shop, and a aquaculture project housed in greenhouses (Figure 8). The waste water to fed to ponds on the adjacent golf course.

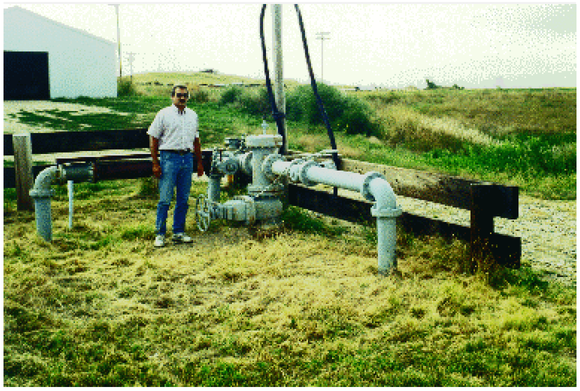

Figure 7. Lake Waggoner Well with Steve Wegman

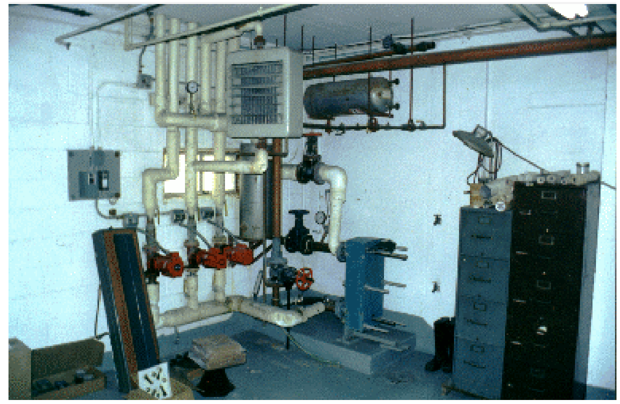

Figure 9. Plate heat exchanger and unit heater in water treatment building.

The water treatment plant uses a plate heat exchanger to separate the geothermal water from treated, which is then run through unit heaters for space heating (Figure 9). The highway maintenance shop (Figure 10) uses PVC pipe embedded under the concrete for heating the shop floor. Two-inch diameter schedule 40 pipe is place in five loops under the 114 ft x 60 ft (35 m x 18 m) floor slab. The maintenance personnel can work comfortably all winter in this building.

Min-Kota Fisheries, based in Renville, Minnesota, a part of Minaqua Fisheries Coop of Chicago, New York and Toronto, raises talpia inside a series of greenhouses (Fig. 11). These greenhouses with an area of 114 ft by 300 ft (35m x 91 m) were originally constructed to raise vegetables and flowers. They are now used to raise juvenile fish for shipment to Minnesota, where the fish are then raised to maturity and sold as fresh fillets

Figure 10. Highway maintenance building.

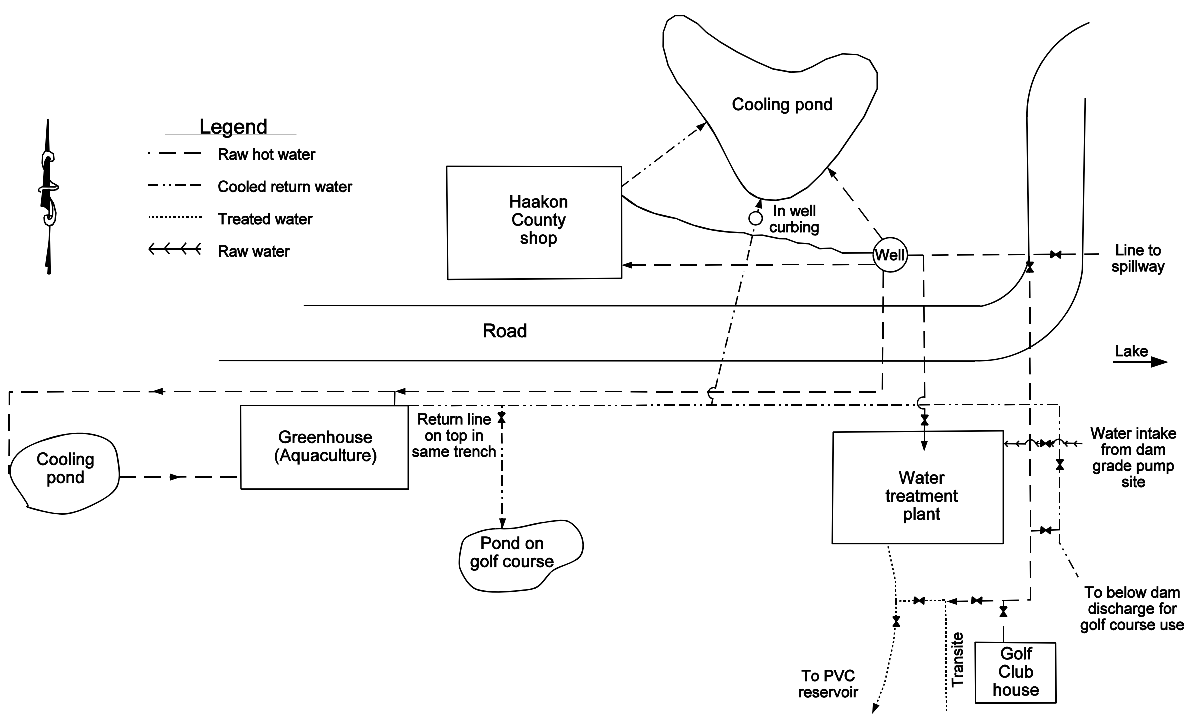

Figure 8. Schematic of the geothermal supply system at Lake Waggoner

Figure 11. Greenhouses with storage tanks on right.

The 157ºF (69ºC) water is delivered to a cooling pond (see Figure 8) where it is reduced in temperature by aeration. It then goes to two 5,000-gallon (18.9-m^3) tanks wher it is kept at approximately 95ºF (35ºC) in one and 85ºF (29ºC) in the other. The storage temperature may be as high as 105ºF (40ºC) in the winter to allow for heat loss. The higher temperature water is then piped into nine lined earth ponds, 20 ft by 100 ft fy 35 ft deep (6 m x 30 m x 1 m) (Figure 13. These ponds, kept at 92 to 94ºF (33 to 34ºC), are the brood ponds were the fry are first raised after birth. After about a week, the fry are transferred to sixteen 600-gallon (2.3-m^3) concrete tanks (Figure 14). These tanks receive water from the lower temperature storage tank and are kept at 82 to 84ºF (28 to 29ºC). After about 30 days in these tanks, the fingerlings are shipped to Minnesota where they are raised to adult size. The fingerlings at this time, average 1.5 to 2 inches long (3.8 to 5.1 cm) and weigh 0.035 to 0.105 oz (1 to 3 grams) each. When at maturity, the fish sell for $1.80 to $2.10 per pound ($4.00 to $4.60 per kg) live and $6.00 per pound ($13.20 per kg) as fillets. The building is also heated with large unit heaters suspended from the ceiling (Figure 15).

Figure 12. Aeration pond with storage tanks and greenhouses in background.

ACKNOWLEDGMENTS

I wish to thank Steve Wegman of the South Dakota Utilities Commission for arrangement the visit to Philip for me, Charles Ekstrum, president of the First National Bank who gave us a tour and explanation of the city heating system, and William DeLayne, the maintenance person at Haakon School for the tour and explanation of the school system.

Figure 13. Lined earth fish ponds.

Figure 14. Concrete fish tanks.

Figure 15. Unit heaters with Pat Seager, manager and Steve Wegman.

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Childs, F. W., L. D. Kirol, R. D. Sanders, and M. J. McLatchy, 1983. "Description and Operation of Haakon School Geothermal Heating System," *Geothermal Resources Council Transactions*, Vol 7, Davis, CA, pp. 579-584.

MIDLAND, SOUTH DAKOTA GEOTHERMAL DISTRICT HEATING

John W. Lund
Geo-Heat Center

Midland, South Dakota, population 250 has a geothermal district heating system unreported in the literature. The system exists due to a joint venture between the school district and the city back in the early 1960s. The project was essential since the city needed a source of domestic water and the school district needed to reduce their heating costs. With the help from faculty from the South Dakota School of Mines, the support and encouragement of the mayor, Jerry Nemec, and the perseverance of city utilities operator, Ruben Vollmer, the system was constructed piece by piece, often by trial and error.

This small town, 60 miles (100 km) west of Pierre on Highway 14, was established in 1890. The first hot water wells were dug by the railroad back in about 1906, when the Chicago North Western originally went through the area. This was the only source of water available for use in the steam engines. The hotel in Capa, a community about 10 miles (16 km) east of Midland, was the first to put the water to use in a hot pool for bathing. It proved very successful not only for bathing, but as a health aid as well.

The first geothermal use in Midland was the establishment of the geothermal mineral baths in the old Bastian Hotel in 1939 by John and Violet Stoppel. The well for the newly named Stoppel Hotel was drilled based on successful wells in the small communities of Capa to the east and Nowlin to the west. Since these communities were not located on the main highway, Midland was selected by the Stoppels for their bath house and hotel (Figure 1). The well drilled to 1784 feet (544 m), produced 33 gpm (2 L/s) of 116ºF (47ºC) water. An outside tank and cooling tower is used to cool the water for the baths (Figure 2). An addition to the hotel added three dressing rooms and three bath tubs filled with hot mineral water continually flowing through them. The hotel is also heated by geothermal heat from the well during the winter months.

Figure 1. The Stoppel Hotel with the bath area on the right.

Figure 2. Storage tank and cooling tower for the Stoppel Hotel.

A municipal well was drilled on the hill above town in 1960, and the artesian hot water was used to heat the grade school and high school buildings in 1964. In 1969 a second well was drilled next to the school buildings at a cost of $75,000. This well drilled to a depth of 3300 feet (1006 m), produced 152ºF (67ºC) water (Figure 3 and 4). The shut-in pressure was measured at 260 psi (1.79 MPa), and when allowed to flow produced 180 gpm (11 L/s) at 10 psi (69 kPa). Originally, the geothermal water was used to heat residences adjacent to the school, but the high pressure caused problems, and thus this use was discontinued. The alternate fuel in town is propane. The chemical analysis of the water in July of 1997 gave (Table 1):

Table 1. Chemical Analysis of Midland Well Water

Total dissolved solids	1506 ppm (mg/L)
Chloride	37.8
Iron	3.3
Manganese	0.1
Sulfate	840.0
Bicarbonate	126.0
Calcium	268.0
Magnesium	66.6
Sodium	24.5
Potassium	9.4
Fluoride	2.4
Nitrate	<0.1
pH	7.72

Figure 3. Well building with school in background.

Shortly after a new fire hall was built in 1981, the city ran a hot water line to it for heating purposes, as the city has an agreement to heat and maintain this building. Soon the Legion Hall and Community Library were added to the line, along with the building housing a bar and restaurant. The waste water was then used to water cattle, before being disposed of into the Bad River. The school heating line provides water to the city water treatment plant, with the excess water again used for cattle watering.

Figure 4. Geothermal well with Ruben Vollmer.

The present well now supplies hot water for heating to the two school buildings, a church, campground buildings and pool, and car wash through a single pipe high-pressure line at

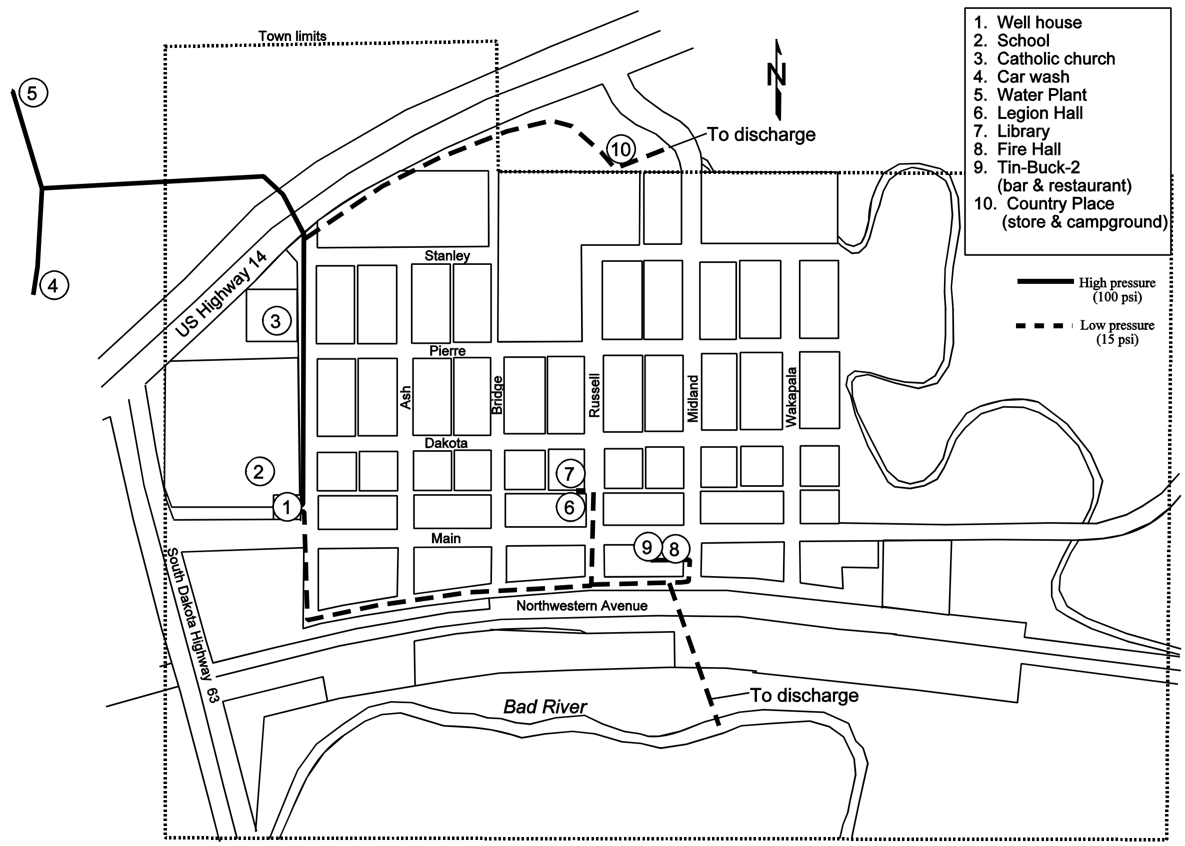


Figure 5. Schematic of the piping system routes in Midland.

100 psi (0.69 MPa) and to four downtown buildings through a single pipe low-pressure line at 15 - 20 psi (103 - 138 kPa) as shown in Figure 5. The high-pressure line finally delivers water to a cooling pond and water treatment plant on the hill about a mile (1.6 km) north of town. The treated water is then return to town as the domestic water supply. Waste geothermal water from the city loop and from the campground is discharged into the Bad River--the same river that Philip uses for their waste geothermal water discharge. In addition, there is a hot water valve at the well where ranchers can obtain hot water for their stock watering tanks in the winter, and highway maintenance personnel and ranchers clean their equipment in the summer.

The swimming pool and heating system was constructed for $2,000, due to the encouragement of Governor Miller, who challenged the various communities of the state to develop physical fitness programs.

The water from the well is divided into to lines (Figure 6). The high pressure line consists of schedule 80 CPVC plastic pipe supplying water to the water treatment plant. The two school buildings are connected in parallel to this line at the well house and are supplied up to 70 gpm (4.4 L/s). At the school there are two separate plate heat exchangers, one for each building. A maximum of 7°F (4°C) is taken out of the geothermal water before it is returned to the main supply line. The secondary side, supplying 140°F (60°C) water to the buildings, is a low pressure system. The building heat is supplied through unit heaters in the gymnasium and wall registers in the classrooms. The system has had trouble supplying heat to the building on the north side, especially with a wind at -20°F (-29°C). At this time the room temperature drops to 60°F (16°C), and a black chemical scale (probably bornite - a copper-iron-sulfate deposit) is deposited on the primary side of the plates (Figure 7). With cleaning of the plates and adding more plates to the heat exchanger, this problem will probably be solved. Hot domestic water is supplied directly to the building from the geothermal line.

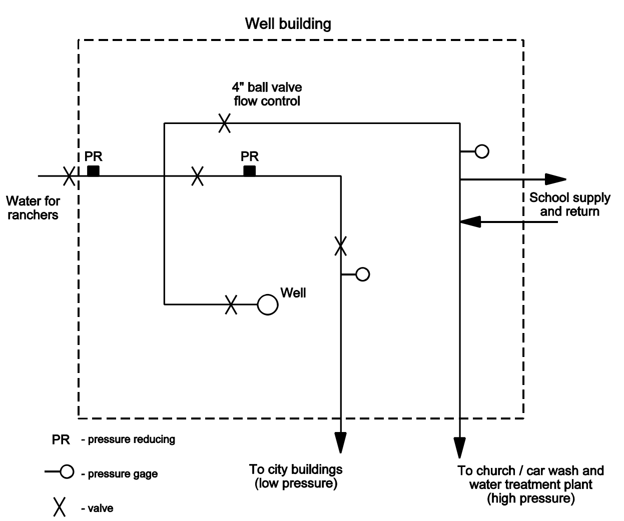


Figure 6. Schematic of the pipelines leading from the pump house.

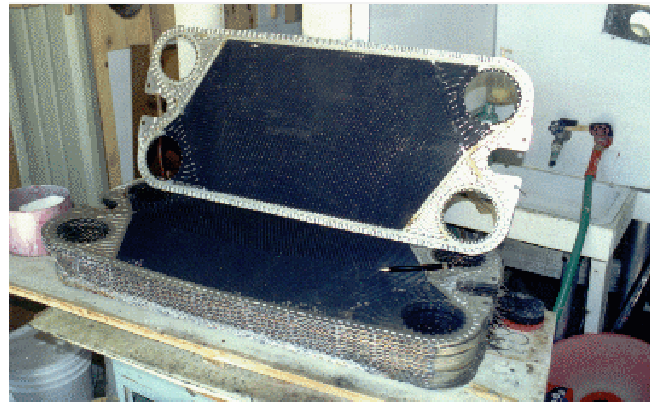


Figure 7. Bornite deposits on plates of school heat exchanger.

The high-pressure line then run past the Catholic Church were a plate heat exchanger, buried in a vault, provides heat to the building through a pumped secondary loop. Next the main line supplies water to the Country Place store and camp ground, controlled by a pressure reducing valve, and used to heat the swimming pool in the summer. The waste water is dump into a ditch which runs to a stream. In winter cattle and horse often will stay along this disposal ditch to take advance of the warm water. The main line then goes past the open air car wash, where it is used directly to heat the floor slab using ½-inch (12-mm) diameter tubing in the concrete slab, and for the wash water (Figure 8). Finally the line terminates in the cooling pond at the water treatment plant--supplied with about 80 gpm (5.0 L/s) in winter and 110 gpm (6.9 L/s) in summer.

Figure 8. The geothermally heated car wash.

The low pressure line is constructed of 1.5-inch (38-mm) PVC uninsulated pipe and supplies 3.0 gpm (0.2 L/s) of 140°F (60°C) water to four buildings where 25°F (14°C) ΔT is removed. Geothermal water is supplied directly to Modine heaters (Figure 9) in the Legion Hall, Library and Fire Hall (Figure 10) with the waste water being returned to the same line. The Tim-Buck-2 Bar and Restaurant is supplied heat through a homemade heat exchanger of ½-inch (12-mm) copper pipe inside 1.5-inch (38-mm) PVC outer tube. The secondary water then supplies heat to an air-duct fan. The waste water from this line finally disposed into the Bad River.

Figure 9. Modine heater in the Fire Station.

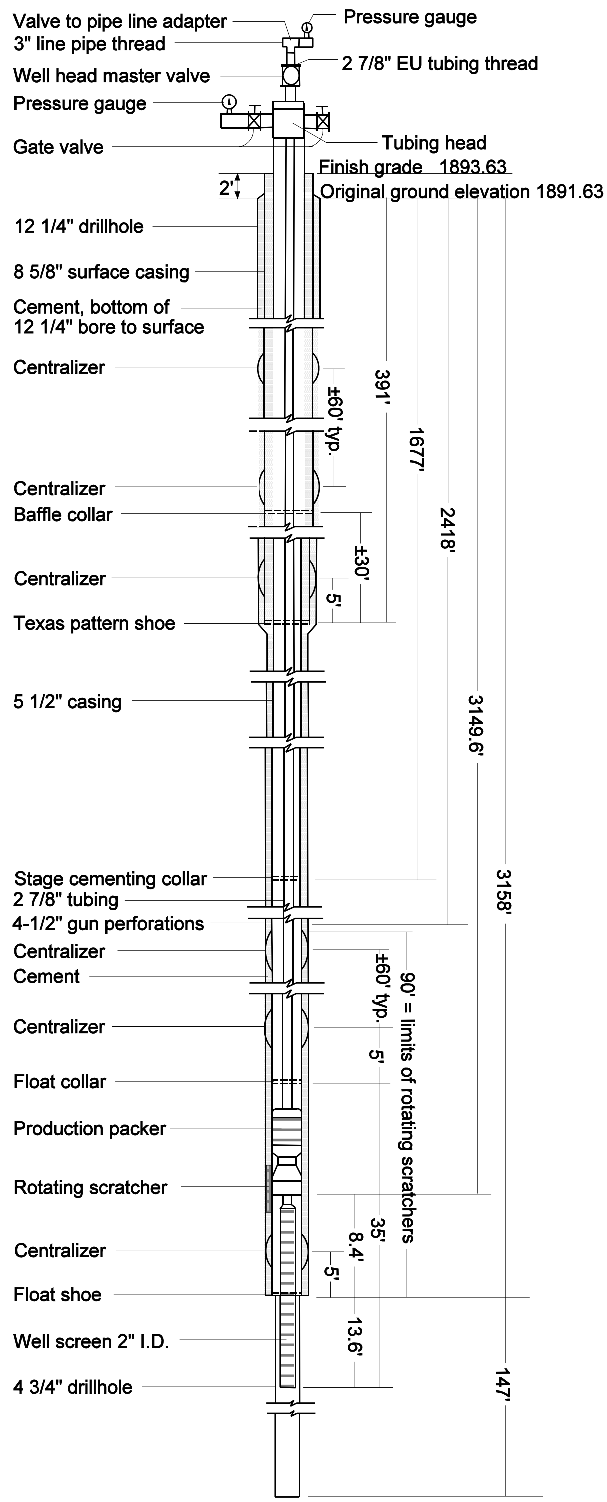
Figure 10. Fire station, Tim-Buck-2 Bar and Restaurant.

SUMMARY

A total of approximately 30,000 square feet (2,800 m^2) of floor space is heated by geothermal in Midland. The high pressure line uses 80 gpm (5.0 L/s) and provides a 7°F ΔT (4°C), and the low pressure line uses 3 gpm (0.2 L/s) and provides a 25°F ΔT (14°C) at maximum use. The system then has a peak power of approximately 0.1 MWt and an annual use of 834 million Btu (0.24 GWh). This provides as estimated annual saving in propane cost of $15,000 to the community.

ACKNOWLEDGMENTS

I would like to thank Jerry J. Nemec, mayor of Midland, for providing a critical review of this article, to Ruben Vollmer, the city utilities operator, and to Bob Sheeley, school maintenance person for their assistance during my visit to Midland. Mr. Vollmer was especially helpful is diagraming and explaining the operation of the system to me.



Midland well profile.

GEOTHERMAL HEAT PUMPS IN PIERRE

Steve Wegman
South Dakota Public Utilities Commission
Pierre, SD

There are two municipal connected heat pumps in Pierre, South Dakota. They are South Dakota Discovery Center and Pierre City Hall (Figures 1 and 2). Both systems now utilize plate heat exchanger between the city water loop and the building loop. In-coming water is pumped to a pressure of 110 to 120 psi (760 to 830 kPa) in order to reenter into the city water main. The water then passes through a plate-type of heat exchanger, 1 to 3°F (1 to 2°C), is removed or injected into the water (Figures 3 and 4). This heat removal or injection is due to if the building is in a heating or cooling mode.

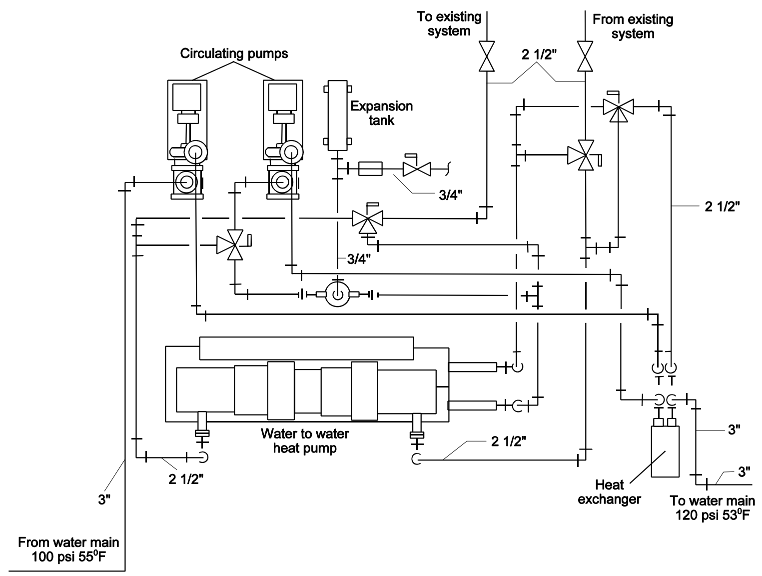


Figure 1. Schematic of City Hall heat pump system.

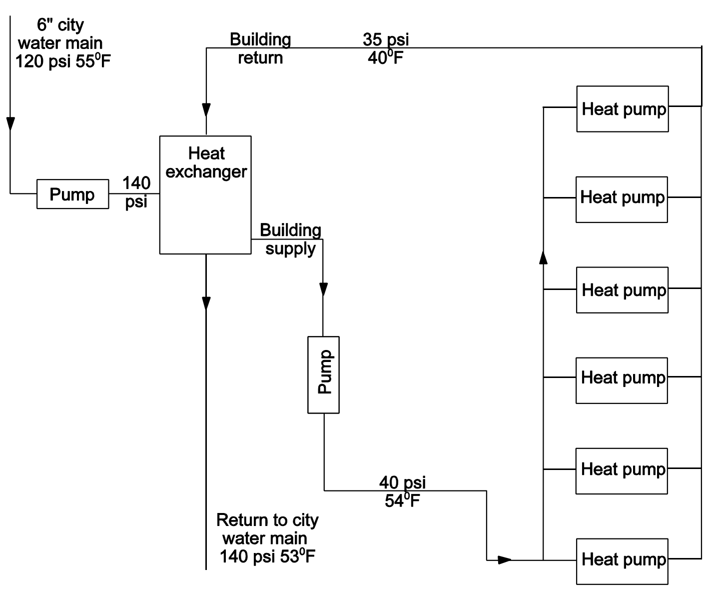


Figure 2. Schematic of Discovery Center heat pump system.

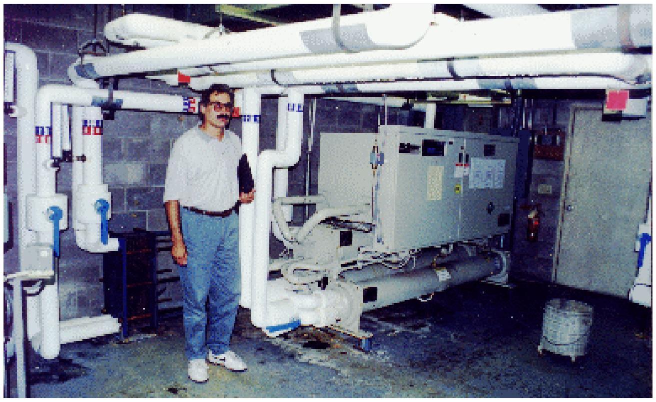


Figure 3. City Hall geothermal heat pump.

Figure 4. Plate heat exchanger in basement of Discovery Center.

The building water loop is operated at a much lower pressure typically 20 to 30 psi (140 to 210 kPa). This water flows through the heat exchanger and then to the heat pumps where conditioned room is heated or cooled. The building water loop temperature leaving the heat exchange is typically 53 to 57°F (12 to 14°C). As the heat pump removes or rejects heat, the building water loop temperature will decrease or increase by 10°F (5.6°C) before it returns to the heat exchanger.

The South Dakota Discovery Center and Aquarium is located adjacent to the Missouri River in Pierre. Built in 1932 as a WPA project, the building was first used for electric power generation. Because of the 6 diesel-powered electric generators housed in the building, it was designed to lose heat.

The facility is made up three levels with a total building volume of 360,000 ft^3 (10,200 m^3). The basement, approximately 9000 ft^2 (836 m^2), is currently used for storage and classrooms. Exhibit space occupies the second level of the building, also covering approximately 9000 ft^2 (836 m^2). A mezzanine makes up the third level covering 2000 ft^2 (186 m^2).

Built of masonry construction, the facility has no insulation in the sidewalls. The roof is built to an R-21 value. New double-glazed windows make up 30% of the building surface area. Pierre has a design temperature of -15°F (-26°C), and the building has a design heat loss of 1.5 million Btu (1.6 GJ) per hour.

In the spring of 1989, officials from the city of Pierre decided to utilize the building as a science and technology center. At that time, the building was being used as a city shop and garage. Heated with a hot water boiler fired by Number 2 fuel oil, annual heating costs were in excess of $20,000 based on 50 cents per gallon (13cents/L) fuel oil. City officials wanted to improve the energy efficiency of the building without changing the historical features. These restrictions would not allow for removing any glass from the walls nor changing the appearance of the building. Adding insulation to the side walls was not possible.

Figure 5. Discovery Center building.

After reviewing the various options available, a system was selected using the city municipal water supply as a heating and cooling source. The water-to-air heat pump system selected has the following characteristics:

- Five 25-ton (87.5 kW) water-to-air heat pumps connected by a parallel piping system.
- Water is delivered to the building by a 6-in. (15-cm) water main at 100 pounds per square inch (689 kPa). Two 100-gallon (6.3 L/s) pumps then increase the water pressure up to 150 pounds per square inch (1034 kPa). This increase in pressure is needed to overcome piping and heat exchanger resistance. Higher pressure also insures that the water cannot be contaminated by the lower pressure refrigerant.
- Water is piped around the building in 2-in. (5-cm) copper pipes with a mechanical balance valve maintaining proper flow through the heat pump and heat exchanger. The water is supplied at a constant flow and consistent temperature of 58°F (14°C).
- When heating or cooling, a compressor starts and the air circulation fan moves the air around the building.
- The water changes only 1°F (0.6°C), plus or minus, as it moves through the system.
- The water is now returned to the city water main for reuse.

Total annual energy usage for the building has been approximately 66,000 Btu per ft^2 (975 MPa/m^2) or $0.88 per ft^2 ($9.47/m^2). This demonstrated that water-to-air heat pumps can provide a viable heating/cooling source for buildings where traditional energy conservation techniques cannot be used.

ST. MARY'S HOSPITAL, PIERRE

Steve Wegman
South Dakota Public Utilities Commission
Pierre, SD

The geothermal project at St. Mary's Hospital (Figure 1) originated with an Energy Use Analysis conducted by Kirkman, Michael and Associate in 1976. In the 1977, the U.S. Department of Energy offered grants for demonstration of geothermal energy projects. The St. Mary's Hospital was one of two hospitals selected in the United States. The project, costing about $718,000, was 75% funded by the U.S. Department of Energy.

Figure 1. St. Mary's Hospital building supplied with geothermal heat.

The system temperature was originally 106°F (41°C) from a 2,200-ft (670-m) artesian well drilled on the hospital property in 1980 (Figures 2 and 3).

Figure 2. Well house and exchanger building.

Heat is extracted from the geothermal water from three heat exchangers located inside a small building at the well site (Figure 4). The cooled geothermal water is discharged into the Missouri River located about 1,000 ft (300 m) away.

Figure 3. Well with Steve Wegman.

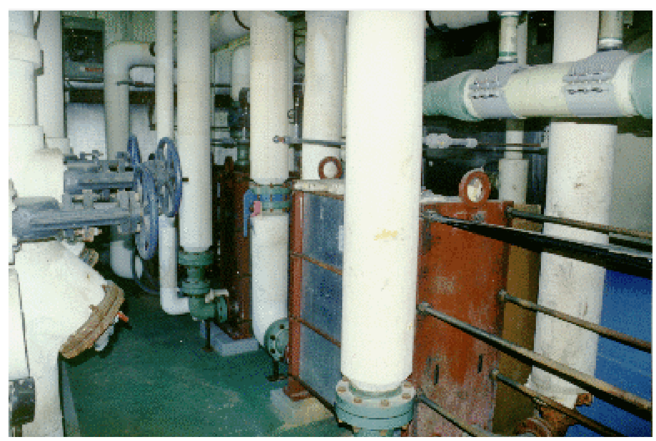


Figure 4. Plate heat exchanger in exchanger building..

Exchanger 1 heats the fluid in a closed loop to 100°F (38°C) for space heating. After giving up its heat in the hospital, the fluid returns to the exchanger at 75°F (24°C) for reheating. Exchangers 2 and 3 preheat domestic hot water from 55 to 100°F (38°C). A conventional oil-fired unit then heats it to the required 140°F (60°C).

Geothermal energy (115 gallons per minute of 100°F water)(7 L/s at 38°C) will provide all the space heating requirements for the new addition, supplying as much as 2 million Btus per hour (2.1 GJ/h). But, geothermal application

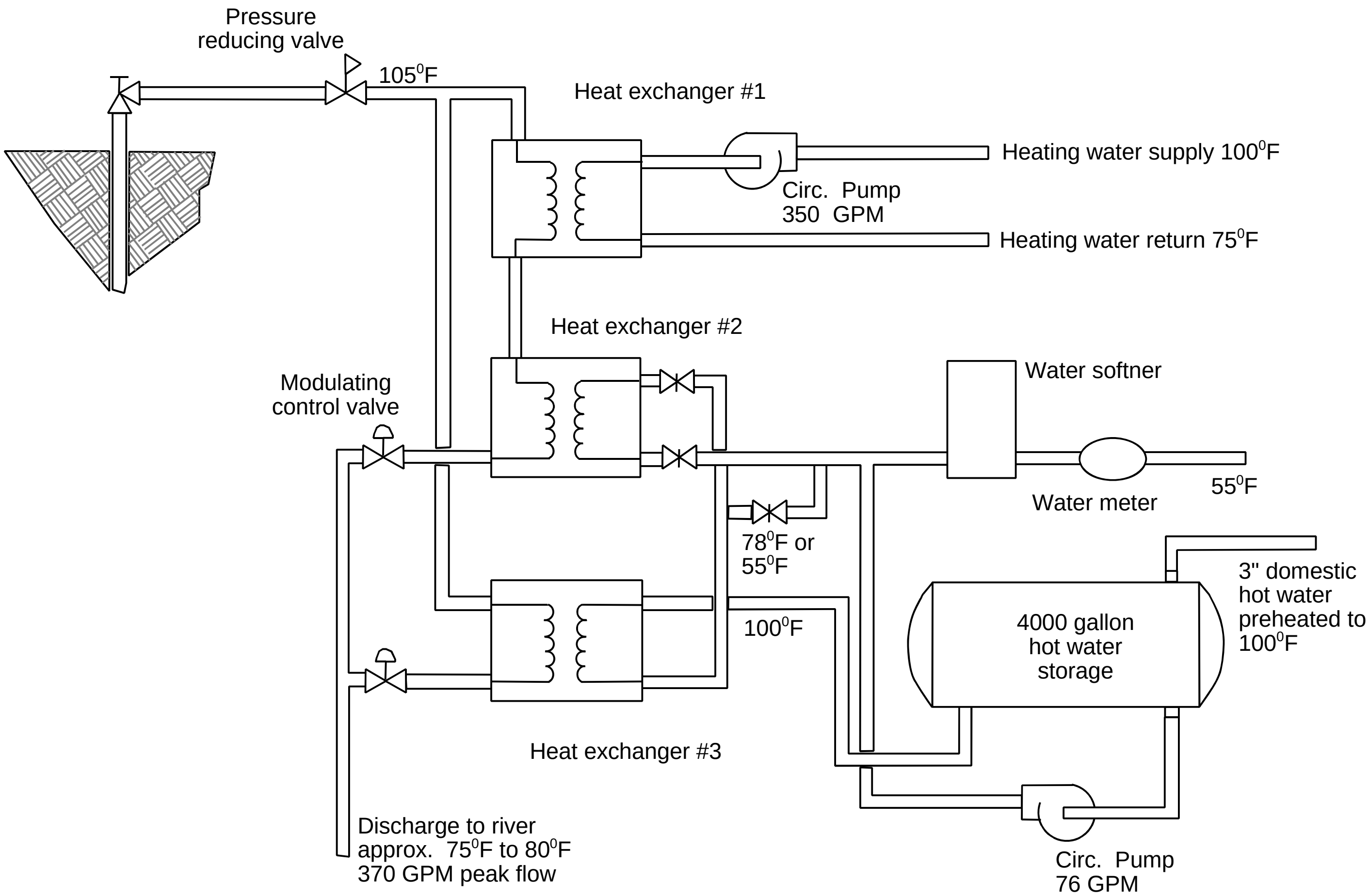


Figure 5. Well house and exchanger building schematic.

to the existing buildings is limited because the primary space heating system requires steam. Two systems were adapted: (1) a fan coil systems, which circulates 50ºF (10ºC), water to provide air conditioning in one section of the building Was modified to use 100ºF (38ºC) water to also provide heat; and (2) the fresh air ventilation system was adapted to geothermal (Figure 5). Hospitals are required to introduce a continuous flow of fresh air into the building 15,650 cubic feet (443 m^3) of air per minute from outside air temperature which can be -35ºF (-37ºC) in the winter. The U.S. Department of Energy was very interested in the economics of the St. Mary's experience with the 106ºF (41ºC) water which is considered to be marginal for heating purposes.

About 1985, St. Mary's abandon the domestic hot water portion of the project, but continued to use the space heating portion. In 1992, the geothermal well developed a leak at about 1,000 feet (300 m) below the surface. The hospital repaired the well and continues to use the geothermal water for space heating. In 1944, St. Mary's converted the existing oil-fired system to natural gas and retained the geothermal water for space heating.

Originally the project was to save $100,000 per year in oil; but, the savings was more like $25,000 per year with oil and when natural gas was installed, the savings is more like $35,000 per year.

GEOTHERMAL PIPELINE

Progress and Development Update
Geothermal Program Monitor

GENERAL

Geo-Heat Center Update

Kevin Rafferty and Tonya Boyd of the Geo-Heat Center have recently prepared a "Geothermal Greenhouse Information Package" publication. This package of information is intended to provide a foundation of background information for developers of geothermal greenhouses. The material is divided into seven sections covering such issues as crop culture and prices, operating costs for greenhouses, heating system design, vendors and a list of other sources for information. Copies are available from the Geo-Heat Center.

GRC Geothermal Pioneer Award

The Geothermal Resources Council (GRC) recently awarded Paul J. Lienau and John W. Lund the group's 1997 Geothermal Pioneer Award. The award, presented at an honors and awards luncheon in Burlingame, California, recognized the two men for their development efforts in the utilization of geothermal resources. Under Lienau's direction, the Geo-Heat Center's professional staff engaged in research and development activities, made numerous national and international presentations and developed a resource library. Lienau retired as Director in June, after being at Oregon Institute of Technology since 1968. Lund, the Center's current Director, has received numerous awards for teaching and scholarly achievements, and has participated in national and international geothermal research projects. Both have been involved in geothermal projects for over 20 years and have participated in numerous GRC activities.

MEETING

The 23rd Stanford Workshop on Geothermal Reservoir Engineering will be held at the Holiday Inn, Palo Alto, CA, from 26-28 January 1998. The aims of the workshop are: 1) to bring together engineers, scientists and managers involved in geothermal reservoir studies and development, 2) to provide a forum for the exchange of ideas on exploration, development and use of geothermal resources, and 3) to enable prompt and open reporting on progress. The workshop registration fee is $300 (before Jan. 1), proceedings $30 and field trip to The Geysers on the 29th ($30). Information can be obtained from Dorie M. Wolf, Department of Petroleum Engineering, Stanford University, Stanford, CA 94305-2220, Phone: 650-725-2723, Fax: 650-725-2099, E-Mail: dorie@pangea.stanford.edu. Additional information and registration forms can also be obtained by E-Mail: http://ekofisk.stanford.edu/geoth/abstrregister98.html.

CALIFORNIA

The Geysers Effluent Injection Project

Energy producers at The Geysers plan to start injecting Clear Lake water into the steam fields today (Sept. 26) as part of a $45 million project aimed at reviving the world's largest geothermal complex. The first-of-its-kind project, which mixes fresh water and treated effluent from Lake County, may become the model for Santa Rosa's wastewater disposal system. But, it could be weeks or months before geothermal operators see an increase in steam pressure at their electric generating plants.

Work is finished on a 29-mile pipeline from Clear Lake that can carry up to 5,400 gallons of water per minute to The Geysers. The pipeline, pump station, storage tanks and other elements of the system have been tested and they all performed well according to Mark Dellinger, Lake County's resource manager. The water started flowing into steam wells operated by Northern California Power Agency, a consortium of cities that included Healdsburg and Ukiah. The following week, the Lake County water is expected to begin flowing into geothermal wells operated by UNOCAL and Calpine, two companies that supply steam to PG&E's generating plants. In all, the imported water will serve 24 steam wells and six power plants in Sonoma and Lake counties. Engineers say injection could restore 70 MW of power, enough to serve 70,000 households.

The geothermal industry is sharing the costs, and the state and federal governments are also contributing to the project. During the early stages of the project, the flow will be mostly fresh water from Clear Lake. But, more wastewater will be added as time goes by. Santa Rosa is currently considering a similar pipeline to The Geysers as a way to dispose of treated wastewater from its regional treatment plant; however, the project could face environmental opposition. In Lake County, pipelines critics warned about possible wastewater spills, and the prospect of earthquakes caused by water injection. A Santa Rosa pipeline would serve a different part of The Geysers and would probably cost more than $200 million.

On October 16, the Lake County pipeline will be dedicated by representatives of the county, state, federal government and the geothermal industry (Steve Hart, *The Press Democrat*).

The Geysers Effluent Injection Project Dedication

Dedicated on October 16, 1997, the world's first waste water-to-electricity system became one of America's premier examples of genuinely sustainable development. The waste water from three communities is recycled through a geothermal steam field to create enough electricity to sustain the communities' power needs indefinitely into the future. A 29-mile pipeline carries 7.8 million gallons per day of treated waste water effluent and make-up water from Lake County, California, treatment plants to three Geysers geothermal steam supplies: Unocal Corporation, Calpine Corporation and the Northern California Power Agency (NCPA). These steam suppliers operate secondary pipelines that distribute the effluent to geothermal injection wells. Power plants operated by NCPA and Pacific Gas & Electric Company received steam supplies created by the effluent injection. Depending upon steam recovery rates from the injected effluent, the project will result in a gain of approximately 70 MW in power output. This will equate to as much as 625,000 MWH of clean, low-cost electricity generation annually for the originating communities and millions of other California consumers. In addition to these energy benefits, the project will also provide a long-term, environmentally-superior method of waste water disposal for the originating communities of Clearlake, Lower Lake, and Middletown; and help create and retain jobs that depend on effective waste water systems and a viable geothermal industry.

Construction of the effluent pipeline and associated waste water treatment plant improvements total approximately $45 million. The public/private financing plan uses county waste water funds, federal and state financial assistance, and Geysers operator's funding. The Geysers operators will also spend an additional $7 million on secondary distribution and injection facilities within the geothermal steam field.

The main effluent pipeline will be owned and operated by the Lake County Sanitation District to a point of delivery near Hwy 175, Unocal, Calpine and NCPA will own and operate the final segment of pipeline and the pump stations up to The Geysers. NCPA will use the effluent-based steam in its own power plants, and PG&E will purchase effluent-based steam from Unocal and Calpine for its power plants (from material developed by Mark Dellinger and Eliot Allen)(see also *GHC Bulletin*, Vol. 18, No. 1 for more details).

Five Eras of Geothermal Energy - New Publication Highlights the History of The Geysers

In the panorama of geothermal events at The Geysers in northern California, five historical eras overlap in a mosaic of time. The intriguing story about man's interaction with geothermal energy in this unique resource area--including a wealth of photographs and information never before published---is now available in *The Geysers Album: Five Eras of Geothermal History*, a beautiful new 52-page book from the California Division of Oil, Gas and Geothermal Resources.

According to author Susan Hodgson, "The first era of untouched wilderness ended abruptly as the second era began 12,000 years ago, when Indians in the region first found The Geysers." The era to follow was the age of "organized tourism" that began around 1848.

"Users in these early eras focused on geothermal surface features as sources of pleasure and cures" says Hodgson, who notes that while Native Americans may still visit thermal features at The Geysers, "most tourism ended in 1980 when the last remnants of The Geysers Resort were razed."

The fourth and fifth eras of man's interactions with the area include the age of electrical power development, generated with steam extracted from the field's vast, underground geothermal reservoir. "The fourth era began in 1921 and ended in the early 1930s, to generate electricity to light The Geysers Resort," notes Hodgson.

Sparked by that legacy, she continues, "The era of modern power development began in 1955, when the first modern steam well was drilled in the area, and continues today." Indeed, though peak production leveled off in the mid-1980s, The Geysers still generates more electricity than any other geothermal field in the world

Copies of *The Geysers Album: Five Eras of Geothermal History*, are available for only $5.00 each from the California Division of Oil, Gas and Geothermal Resources, 801 K Street, MS-20-20, Sacramento, California 95814-3530. Telephone: (916) 445-9686, Fax: (916) 323-0424 (*GRC BULLETIN*, Vol. 26, No. 9).

IOWA

EPRI and Interstate Power Company Forge Partnership

EPRI and Interstate Power Company have forged a partnership to promote geothermal energy technology for commercial and residential use, including a regional Geothermal Information Office (GIO) located at Interstate Power's corporate headquarters in Dubuque, Iowa. Interstate Power is already conducting a broad geothermal assistance program (use geothermal heat pumps) for both residential and commercial customers, and will incorporate this program to provide a wider range of service to its customers.

The utility and EPRI recently were instrumental in having geothermal technology chosen for the upcoming construction of a professional ice arena in Dubuque. The renewable energy source will heat the facility, while simultaneously creating the ice skating surface and will also provide energy for heating the arena's water. The new arena will also provide a large percentage of the energy needed to heat an adjacent shopping complex, and plans are underway to use geothermal energy in the development of several local subdivisions (EPRI, *End-Use News*).

WASHINGTON, D.C.

Geothermal Energy Association's New Website

The first phase of the Geothermal Energy Association's (GEA) new website is now on the Internet and can be found at http://www.geotherm.org. The GEA's website currently displays basic information, including a brief description of the organization, its member companies, GEA's Board of Directors and staff, a calendar of events, some geothermal "factoids" and links to other geothermal sites.

Planned enhancements to the GEA website include the addition of photos and graphics, information about geothermal projects involving GEA members, a publications list (with capability to download listed documents, links to GEA member company websites, summaries of GEA's programs and activities, and information on joining the GEA (News Briefs, *GRC Bulletin*).

WYOMING

Yellowstone National Park

Nearly dormant for 20 years, Giant Geyser has erupted 33 times this year. Giant has erupted every three to four days during the past two months, a rate matched only between 1952 and 1955. After the 1959 Hebgen Lake earthquake, Giant rarely erupted and Grotto became more active--typical of shifts in the areas thermal energy. Giant is located in the Upper Geyser Basin, about a mile southwest of Old Faithful. It produces a tower of water up to 250 ft (76 m), twice the height of Old Faithful. The eruptions usually last for more than an hour, spewing about one million gallons (3,800 cubic meters) of boiling water. Giant's awakening coincides with a renewal of activity in the nearby Splendid Geyser, which has been dormant through most of this century. The Splendid, Giant and nearby Daisy Geyser, which also has shown increased activity, could be linked through the underground tunnels and vents responsible for much of Yellowstone's thermal activity (*Oregonian*, Nov. 16, 1997).

COSTA RICA

Oxbow Power Corp. Selected to Lead International Consortium

In mid-September, the Costa Rican government upheld the selection of an international consortium led by Oxbow Power Corp. (West Palm Beach, FL) to develop the country's first Build-Own-Transfer (BOT power project - the 27.5 megawatt Miravalles III geothermal plant in Guanacaste Province. Other members of the winning consortium are Baruberi Corp. (Tokyo) and Oxbow Services, Inc. (Reno, NV). Negotiations on project contracts are expected to begin soon (*GRC Bulletin*, Vol. 26, No. 9).

ST. VINCENT (CARIBBEAN)

La Soufriere Volcano

In July, St. Vincent and Grenadines Communications Minister Jerry Scott said his government will map the geothermal energy potential of the La Soufriere volcano in an effort to reduce the tiny nation's diesel fuel imports. Hydroelectric power generation already produces 44 percent of total energy requirements; but, St. Vincent's diesel import bill reached over $7 million in 1995 (Geothermal Energy Association, *First Alert*).